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# China Report

SCIENCE AND TECHNOLOGY

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17 October 1985

# CHINA REPORT

## SCIENCE AND TECHNOLOGY

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NATIONAL DEVELOPMENTS

HOW TO STIMULATE RESEARCH INSTITUTES

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI /SCIENTOLOGY AND MANAGEMENT OF S&T/ in Chinese No 6, 12 Jun 85 pp 17-18

/Article by Zhu Chuanbo /2612 0278 2672/ of the Central Bureau, State Science Commission/

/Text/ I. "Stimulate" Ideas--Solve the Problem of "Eating Out of the Big Common Pot"/

Administrative departments at all levels should liberate ideas, destroy the old viewpoint of "departmental ownership" and "local ownership," simplify administration and relax authority, gradually implement separate responsibility for administration and research, expand the decisionmaking rights of research institute, relax restrictions and turn them from "subsidiaries" of administrative departments into scientific research entities with relatively independent decisionmaking rights.

Freeing the ideology of research institute leadership from all types of fetters is the key question in "stimulation" of research institutes. The main ideological obstructions that affect "stimulation" research institutes are:

1. The ideology of "the three depends." For a long time, research institutes have eaten out of the state's "big common pot" and have formed an ideology of "the three depends": administrative expenses depend on state grants, scientific research tasks depend on upper levels handing them down to lower levels, and scientific research achievements depend on upper levels to extend and apply them. This is incompatible with "stimulation" of research institutes. An ideology of reform must take root. There should be "independent gateways," self-support in society and exploration of new paths for reform before a new situation can be created in research institutes.

2. The ideology of "specialness." An attack by the floodwaters of reforms in economic systems and in S&T systems is inevitable, but many leading cadres in research institutes emphasize their own "specialness" and block them for various reasons, placing themselves outside the gates of reform.

3. A fear of making mistakes. Any reform has its exploratory side and we must consider the need for safe reforms along with active adovcation of new ideas in

reforms. Reforms would be impossible without new ideas. Many people now are quite anxious about creating ideological instability and they are "looking, moving slowly and not passing." They do not pursue meritorious service but seek only nonimplementation. The result is that no new situation in reforms has been opened up for a long time.

As soon as some comrades mention "stimulation" of research institutes, they fear taking a wrong direction, considering things over and over again, fearing this and fearing that. Only "stimulation" of research institutes will make it possible to promote development of research, improvements in scientific research levels, achieving things quickly and producing more talented people.

4. The ideology of egalitarianism. The wages, bonuses, housing, technical titles and other things of scientific research personnel have been entered through "horizontal teams" for a long time. Everyone was the same and there was no separation according to grade. No individual "standouts" were encouraged, which severely constrained the initiative of vast numbers of S&T personnel. Respect for knowledge, respect for talent and acknowledgement of differences in intelligence requires that we dare to adopt special measures to assist top-notch people to display their talents.

## II. "Stimulate" Research Directions--Solve Problems in the Direction of Services

For a long time, the direction of services in scientific research organs has been restricted either visibly or invisibly to a narrow "zone." "Stimulation" has meant "eating everyone's food" with no chance to "eat one's own food." There should be special qualities in the area of technology and a relative strong capacity for "strain." Four changes are needed to achieve this:

1. A transition from service to departments (or service to localities) to opening up to society and serving all of society. We should destroy the situation of separation by regulations and make the achievement of socioeconomic benefits the focus and home. This will open up our field of vision and provide great latitude in topic selection, and it may permit the achievement of technical cooperation on a large scale. Expanding the spheres of service can "add wings to the tiger" and allow us to seek more partners in cooperation in expanded technology markets.

2. Based on the need of the national economy to readjust its own direction in scientific research, we should change the situation of "large and complete" or "small and complete" in deployment of specializations to form our own technical characteristics, and to increase competitive abilities in technology markets. Based on comprehensive plans for the development of scientific research in China, on laws of demand in technology markets and on the basic conditions in one's own institute, there should be readjustments in the direction of our own scientific research and substantial technical cooperation between research institutes and between institutes and related regions and departments to gradually form our own technical advantages.

3. In arrangements for topic selection tasks, we should integrate the short-term and long-term and focus on the short-term. Scientific research units

engaged in developmental research should expend their primary manpower and capital on technical questions in the national economy that require urgent solutions to derive real social and economic results.

4. Develop many forms of "administration." In conjunction with a focus on "research," research institutes also must develop all types of technical administration professions, greatly extend S&T achievements and develop technical advisory services, design, commissioned personnel training, and other activities. Development of such activities requires full utilization of the existing capital resources of research institutes to work closely around their own direction in scientific research.

### III. "Stimulate" Organizational Structures--Solve Problems of Bureaucratism in Organizational Structures

Organizational structures guarantee actual research directions and tasks. "Stimulation" requires strengthened administrative functions and enriched administrative service structures so that research institutes have free information flows, high efficiency and good capabilities and dynamic management. Strengthening refers to the establishment of highly efficient structures and solution of the current problems of excessive numbers of managerial levels, structural overstaffing, floating assignments and low efficiency:

1. Strengthen plan management, technical management and economic management. Regardless of whether compensated contract system or fund systems have been implemented, both sides in a contract assume technical, economic and legal responsibilities, and there should be strict examination to ensure that scientific research plans, technical indices and the utilization of administrative expenses conform to the provisions of a contract. Economic accounting is the foundation of all reforms in research institutes. This requires that we especially strengthen economic accounting work, train financial accounting staffs suited to the situation in reforms and establish a system of regulations for all types of economic accounting.

2. Strengthen technical information and technology market forecasts. Research institutes should gain victory from the "new." The new depends on information and information depends on research on technical information and research on technology market forecasting.

3. Strengthen intermediate examination capabilities. Research institutes must produce both soft results and hard results, and soft and hard results must be integrated before they have the ability to compete in the market. Strengthening intermediate examination abilities is an important measure for achieving hard results, and it is a necessary link for accelerating the conversion of S&T achievements into social forces of production. Practice has proven that intermediate examination capabilities must be adapted to the overall S&T abilities of a research institute. An excessive intermediate examination capability often means that there are insufficient tasks and idleness. An overly small intermediate examination capability means that tasks "cannot be handled." Both of these situations should be avoided.

4. Cooperate widely with society, establish various forms of associations. The establishment of a pattern of scientific research-production, scientific research-education-production associations is a necessary route for S&T development. This sort of "extensive" pattern is a concrete formula for utilizing the manpower, materials and financial abilities of society and for strengthening the technical advantages of research institutes, and it has enormous vitality.

5. Strengthen administrative, marketing and technical services. To achieve a transition from a solely "scientific research type" to a "scientific research management type," management and technical service work must be strengthened. Comrades with technical and managerial skills should be selected to enrich these departments.

#### IV. "Stimulate" Personnel Management--Solve Problems of Each In His Proper Place

Because people have different qualities, experiences and creative abilities, some S&T personnel prefer to engage in basic research work, while others prefer to engage in technical extension and technical services work. If research institutes are to be "stimulated," then there can be no "indiscriminate action" in personnel arrangements. Make proper arrangements according to the actual situation of each person to use advantages and avoid shortcomings and foster the initiative of everyone.

Those S&T personnel who are adept at basic research and applied research should be encouraged to stand out technically and become scholarly leaders. The conditions should be created for them so that they can fully conquer the peaks of S&T and use pathbreaking results to take their place in scholarly circles in China and abroad.

Those S&T personnel who are adept at developmental research should be encouraged to orient toward economic construction, select topics through practice in production, promote technical and economic progress, corner technology markets through new technical achievements and products and provide the research institutes with guaranteed sources of administrative expenditures.

Policies and measures should be used to encourage some S&T personnel to take up extension and application of technical achievements and technical service work.

Competition in technology markets in essence is competition of talented people. If we wish to "stimulate" research institutes, we first of all must improve the political qualities and technical qualities of personnel to meet the need for knowledge renewal.

#### V. "Stimulate" the Economy--Solve Problems of Capital and Its Turnover Period

The degree to which administrative expenditures are guaranteed is an important indicator of "stimulation" of research institutes. We should work in the following areas to broaden sources of income and reduce expenditures:

1. There should be more and expanded sources of finances. Apart from vertical contract tasks, there also should be a large amount of responsibility for horizontal contract tasks. Apart from income from scientific research contracts, there also should be an intermediate examination capability and technical transfers, technical advisory services, design, commissioned specialized personnel training and other sources of income. Apart from income from within an organization, there also should be income from the organization of various types of associations as well as utilization of all types of capital assistance funds, bank loans and so on from China and abroad.

2. There should be rationally unified utilization of all income in research institutes to foster the maximum economic results. "Dead money" should become "live money," capital turnover should be speeded up and money should be put to the best uses. Examples include collecting capital to develop new technologies with a developmental future, importation of key components and parts from foreign countries. cooperative development with foreign capital and so on.

3. There should be rational proportions for the S&T development funds, collective welfare funds, individual bonus funds and institute director funds that are included in net income.

4. Distribution of individual bonuses should adhere to the principle of more pay for more work and oppose egalitarianism. There should be large bonuses for comrades who truly have made contributions to encourage individuals to stand out and to achieve a clear demarcation of rewards and punishments so as to encourage progress and promote those lagging behind.

5. Increased income and reduced expenses are a pair of "twins" and there is great potential that can be exploited in expenditure reduction in research institutes. Examples include reductions in circulating capital, depreciation of fixed assets and debates concerning topical programs to reduce losses caused by mistaken technical programs and overstocks of expensive equipment.

6. Problems of legality without rationality in financial management should be solved. Financial management in research institutes always has used the method of single-activity enterprise management. When faced with reforms in S&T systems, research institutes are not the same as production enterprises or state organs. New methods should be formulated for their fiscal accounting to solve several problems of legality without rationality.

In summary, "stimulation" of research institutes is not an easy matter. It touches upon all factors in society and within the institutes and is a comprehensive reflection. Administrative departments at all levels should begin by "stimulating" research institutes, dissect the twisted and gnarled relationships, and use a macroview of S&T systems and a microview of management methods for a comprehensive solution so that research institutes truly become research development entities with vigor and make contributions to the four modernizations.

NATIONAL DEVELOPMENTS

MOBILE POSTDOCTORATE SCIENTIFIC RESEARCH CENTERS SET UP

Beijing GUANGMING RIBAO in Chinese 11 Jul 85 p 1

[Article by Zheng Haining [6774 3189 1337]: In Order to Accelerate Training of High-Level Specialized Talent Which Is Needed for Modern Construction, China Will Try Out Mobile Postdoctorate Scientific Research Centers, Enrolling 250 Postdoctorate Researchers Throughout China During 1985 and 1986"]

[Text] It has been learned from the State Science and Technology Commission's Science and Technology Cadres Bureau that in order to accelerate training of high-level specialized talent which is needed for modern socialist construction, the State Council has approved recently a report from the State Science and Technology Commission, the former Ministry of Education and the Chinese Academy of Sciences and decided to try out in China a postdoctorate research system and allocate special funds to set up mobile postdoctorate scientific research centers.

A postdoctorate research system is one which has been formed gradually in certain developed countries since World War II to train outstanding specialized talent. The method and goal of carrying out this system is to set up certain irregular positions in colleges, universities and research organizations and to select certain Ph.D.s to carry out a stage of research work there in order to broaden the scope of their knowledge, further train their ability to work independently and turn them into high-level scientific researchers and teachers.

Since 1981, China has recruited almost 1,000 graduate students to study diligently in China for Ph.D.s. Beginning in 1973, over 3,000 graduate students have been selected to study abroad and have now acquired Ph.D.s one after another and returned to work in China. Certain colleges, universities and research organizations in China which have high academic standards and good scientific research conditions have set up "mobile postdoctorate scientific research centers" and selected certain personnel who have acquired Ph.D.s both in China and abroad to carry out a specific period of research work there. They are not part of the authorized strength of these units' official staff members and workers but have a mobile status prior to acquiring regular work positions. This will be favorable to training high-level scientific researchers, developing academic exchange, selecting the best from a large number, avoiding academic "inbreeding" and giving both Ph.D.s and personnel units more opportunities to choose each other in order to make the best possible use of manpower and talent.

A responsible person from the State Science and Technology Commission's Science and Technology Cadres Bureau told the reporter that setting up "mobile post-doctorate scientific research centers" is an important way to develop talent and also a new task which must be popularized gradually after experimenting and acquiring experience. In 1985 and 1986, 250 postdoctorate researchers throughout China will be enrolled. Postdoctoral researchers will work generally for 2 years at a mobile center. After their work period is completed, they must move out of the center or transfer to the next one. The total working time at different mobile centers must not exceed 4 years. Postdoctoral researchers who do not continue to move may compete for regular positions based on personnel unit advertisements and also arrange for work based on a combination of their aspirations and the needs of the State Science and Technology Commission's Science and Technology Cadres Bureau. During their mobile work center periods, postdoctoral researchers will all be treated according to their seniority as official state workers and be paid temporarily the lowest standard post-wage-reform lecturer (assistant research fellow) wages. After completing the mobile period and arranging regular work and clear posts, they will be paid wages corresponding to their positions. During their mobile periods, postdoctoral researchers' spouses and minor children may also move with them.

In order to encourage and support outstanding young talented postdoctoral researchers who have scientific research potential and outstanding ability, the state will set up a postdoctorate science fund in order to enable them to acquire favorable conditions in certain areas, develop their scientific research work successfully and mature quickly as high-level research talent.

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NATIONAL DEVELOPMENTS

CAS OPENS DOORS TO REST OF COUNTRY

Hefei ANHUI RIBAO in Chinese 17 Jun 85 p 1

/Article: "The Structural Analysis Research Center and the Laser Spectroscopy Laboratory of the Anhui Optical Machinery Institute Will Be Opened to All of China--Implement the Decisions on S&T Reforms, Strengthen Horizontal Linkages and Cooperation"/

/Text/ The Chinese Academy of Sciences /CAS/ invited experts and professors in related areas to Hefei City from 8 to 10 June for evaluation and discussion of opening the Chinese Science and Technology University's Structural Analysis Research Center and the Applied Laser Spectroscopy Research Laboratory of the Chinese Academy of Sciences Anhui Optical Machinery Institute to the rest of the country. Professor Feng Duan /7458 4551/ of the Nanjing University and Professor Qian Linzhao /6929 5259 3564/ of the Chinese Science University headed the discussion meetings. Zhou Guangshao /0719 0342 0664/, deputy director of the Chinese Academy of Sciences and Anhui Provincial Governor Wang Yuzhao /3769 6735 2507/ gave speeches at the opening ceremonies. Selection of certain research institutes and laboratories with the basic research and experiment conditions and specific scientific research and technical strengths for opening up to all of China is a important measure that the Chinese Academy of Sciences has taken to implement the decisions of the CPC Central Committee concerning reforms in S&T systems. The purpose is to create the conditions for developing cooperatives research and carrying out scholarly exchanges with the related scientists and scientific research workers in China. The Chinese Science and Technology University's Structural Analysis Research Center is a laboratory that does analysis and testing as well as comprehensive research on the constituents, structure, defects and shape as well as the physical and chemical properties of various types of materials. This research center has more than 30 types of experimental measures for analysis and testing. The Applied Laser Spectroscopy Research Laboratory of the Chinese Academy of Sciences Anhui Optical Machinery Institute has received state investments in recent years to purchase a number of advanced scientific research instruments and equipment, and it has developed cooperative research with the Quantum Optics Research Institute of the West German /Mapu/ Society, the Shanghai Organic Chemistry Institute, the Anhui College of Medicine and other units. Rather good work has been done in cross molecular beam laser spectroscopy, multiphoton molecular ionization and other areas.

NATIONAL DEVELOPMENTS

SIX POLICIES FOR REFORM OF S&T SYSTEMS

Chengdu SICHUAN RIBAO in Chinese 11 Jun 85 p 1

/Article: "Adhere to Reforms in S&T Systems, RECTify New Corrupt Practices--  
The Sichuan Science Commission Has Received Approval From the Provincial CPC  
Committee To Lay Out Six Policy Limitations"/

/Text/ To guarantee smooth implementation of reforms in S&T sytems, the Sichuan Provincial Science Commission recently requested agreement from leading provincial comrades in the Sichuan CPC Committee to deal resolutely with reforms in S&T systems and rectify new problems related to corrupt practices by laying out six policy limitations:

1. To adapt to the need to open up technology markets, S&T management departments at all governmental levels are setting up various types of technical service and technical development organizations. Being engaged in technical services and work related to transfers of achievements cannot be seen as handling commerce through governmental authority. During the early period of their operation, they received approval for responsible persons and workers in governmental S&T management departments to take up joint posts in these organizations, but they must not receive remuneration.
2. During the reforms, scientific research organs and institutions of higher education are operating technical management and technical development organizations, and they have set up scientific research and production associations and technical economic entities to separate enterprises from party and government organs. Cadres in these units take up joint positions in these organizations, differentiating and separating commercial activities from cadres in party and government organizations.
3. S&T personnel who work in party and government organs and who receive approval from their organization or who carry out organized technical advisory services and who receive rational remuneration according to the related policies and stipulations should not be considered to be engaged in corrupt practices.
4. With a prerequisite of completing the work of their present position and approval from their organization, truly skilled S&T personnel who have taken leadership posts in party and government organizations or who are engaged in technical service work in an organized manner should not be considered to be engaged in corrupt practices if they receive rational remuneration according to related sitpulations.

5. Implement large bonuses for S&T personnel who have made major contributions. Remuneration according to stipulations for S&T personnel that is based on contractual responsibility for scientific research or provision of technical advisory services should not be considered excessive bonuses.

6. During reforms of S&T systems, all problems appearing during implementation of instructions from upper levels in all areas because of a lack of fit with related decisions of the CPC Central Committee and the State Council should be solved through investigation, study and seeking truth from facts and should not be considered corrupt practices.

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CSO: 4008/393

NATIONAL DEVELOPMENTS

LIN SHENG: S&T SYSTEM THAT IS FULL OF VITALITY

Liaoning GAIGE ZHISHENG [VOICE OF REFORM] in Chinese No 6, 10 Jun 85 pp 26-28

[Interview with Lin Sheng [2651 5116], Vice Governor of Liaoning Province and Chairman of the Liaoning Provincial Science and Technology Commission At a Liaoning CPC Committee, Government S&T Work Conference, date not given]

[Text] From 14 to 20 May 1985, the Liaoning Provincial CPC Committee and Provincial Government convened a conference on S&T work to deal with ways to implement the "Resolutions Concerning Reforms in S&T Systems" of the CPC Central Committee. During the meeting, a small group of leaders from the Liaoning Provincial Science and Technology Commission drafted "Certain Resolutions" related to implementation of the CPC Central Committee decisions that served as an important aspect of the discussions and study during the conference. A reporter for this journal met with Lin Sheng, Vice Governor of Liaoning Province and Chairman of the Liaoning Provincial Science and Technology Commission and asked about the drafting of the "Certain Resolutions." They discussed how Liaoning should implement the "Resolutions Concerning Reforms in S&T Systems" of the CPC Central Committee, reform S&T systems and enliven the economy of Liaoning.

Reporter: Comrade Lin Sheng, I first of all would like to ask you to discuss the guiding ideology of the draft "Certain Resolutions," if that is alright with you.

Lin Sheng: The "Resolutions" of the CPC Central Committee discuss nine articles. My understanding of the primary spirit is that it concerns a solution to systemic problems in integration of S&T with production. There are four key provisions. The first is to change the grant system for scientific research units and put an end to "eating out of the big common pot." This is the core question and we must block the "supply system." The second is to open up technology markets and give them an outlet so that S&T achievements enter the realm of circulation and so that there is compensated exchange to open up and enliven scientific research units. The third is to focus on buyer's markets so that new S&T systems can operate. This requires us to strengthen the ability of enterprises to absorb and develop technologies. Compensated transfer

of scientific research achievements is possible only when there are strong buyer's markets, and only then can most scientific research units achieve economic independence. The fourth is that S&T personnel are the carriers and creators of knowledge and technology. Only through the circulation of personnel and knowledge is it possible for comprehensive invigoration. This is an operational mechanism in S&T systems.

Based on this spirit and through integration with actual conditions in Liaoning, the "Certain Resolutions" were formulated.

Reporter: The core of reforms in existing S&T systems is to change grant systems for S&T administrative expenditures and to implement management by categories for administrative expenditures according to the characteristics of different types of scientific research organizations and S&T activities. Please discuss the concrete decisions of Liaoning Province concerning management of S&T administrative expenditures based on the "Resolutions" of the CPC Central Committee.

Lin Sheng: Currently, there are 777 organs engaged in research in the natural sciences in Liaoning Province. Besides 80 scientific research organs operated by institutions of higher education and 379 scientific research organizations operated by factory and mining enterprises, there are 318 independent scientific research organizations that receive direct grants from state revenues. According to statistics for the end of 1978, the annual administrative expenses of these units for S&T activities were about 140 million yuan. If we exclude the 39 research institutes under the Chinese Academy of Sciences and other departments under the central government, Liaoning has 279 scientific research organizations at the provincial, city and prefectural levels. Their expenses for S&T activities amount to about 5.822 million yuan.

Based on the "Resolutions" of the CPC Central Committee and actual conditions in Liaoning, leading comrades in the Liaoning Provincial CPC Committee have pointed out that the elimination of administrative expenditures in scientific research units in Liaoning and the achievement of economic independence can be speeded up. For this reason, the "Certain Resolutions" propose that 3 years' time, meaning up to 1 January 1988, be used to completely eliminate administrative expenditures in 153 industrial scientific research units engaged in technical development, extension and application in Liaoning. Scientific research units engaged in technical development in agriculture can take 5 years or slightly longer to eliminate administrative expenditures and achieve independence. The reduced administrative expenditures will serve as provincial and city S&T development funds that will be used as payment and returned to scientific research units. These administrative expenditures are not to be given to scientific research units as administrative expenditures for bonuses, wages and employee welfare but mainly will be used to develop S&T activities.

In regard to scientific research organizations engaged in social welfare and social services, the "Certain Resolutions" propose that per capita pre-distributed amounts in 1985 be used as a base number to implement a yearly responsibility system. No surpluses and income will be turned over to higher levels.

Establish provincial and municipal S&T development funds, with primacy given to science committees with participation by planning, S&T, financial and banking departments, establish S&T development committees to take responsibility for administration and utilization of S&T development funds. There are four main sources of S&T development funds: 1) Existing expenditures on the three S&T items; 2) Annual increases in fiscal S&T administrative expenditures; 3) Reduced administrative expenditures in scientific research; and 4) Recovered administrative expenditures from compensated contract projects. The S&T development funds are to be used mainly for major scientific research and technical development projects, for new key technical (or industrial) laboratories and intermediate experimental base areas, for construction of S&T development activities, and so on. Major projects should implement open bidding and selection of the best for support.

In the future, utilization of S&T administrative expenditures will change from the past method of uncompensated grants to uncompensated, partially compensated and fully compensated appropriation methods. In addition, banks should actively develop S&T loan activities. During the Seventh Five-Year Plan, a portion of S&T development funds will be set aside each year to serve as credit turnover funds. Based on the projects proposed by S&T departments and the signing of contracts by the units assuming responsibility for the projects, banks will select the best for appropriations.

Reporter: Opening up technology markets and accelerating the commercialization of S&T products is a breakthrough in reforms of S&T systems. How do the "Certain Resolutions" embody this question?

Lin Sheng: Liaoning has made several bold attempts at reform in this area since the 3d Plenum of the 11th CPC Central Committee. We have done a great deal of work related to compensated transfers of S&T achievements and obtained very good results. More than 20,000 technical contracts of various kinds have been appraised and signed in the past few years with a total volume of 310 million yuan. This created 2.7 billion yuan in economic results and caused quite a few enterprises to change from operating at a loss to operating profitably. Technical economic results were improved to a substantial degree. Some 12 technology markets were opened in the cities and rural areas of Liaoning during the last half of 1984 and production is extremely prosperous. The facts have proved that focusing on the commercialization of technology, which is a breakthrough in reforms, can solve many problems in one swoop.

Summarizing the development of technical trade in Liaoning, not only have a technical achievement exchange committee, a technical cooperation consultation committee, a technical development service company and a store that specially handles technical achievements and other forms of diversified administration been created, but their content and scale also are developing in the direction of greater breadth and depth.

Because the operation of technology markets is a new affair, there were differences in the policies and methods formulated in each area and department, which led to some new contradictions. For this reason, we stressed in these "Certain Resolutions" that there should be great efforts to open up technology markets and to implement multilayer, multi-channel and multi-type technical commodity

circulation. We proposed a principle that "both advance together" and that we oppose monopolism and encourage competition so that technology markets are truly opened up and invigorated. In another area, we decided on certain policy measures and organizational measures to open up technology markets. Examples include guaranteeing the legitimate rights and interests of buyers, sellers and intermediaries. The province, cities and counties should set up the corresponding organs and strengthen management. The scope and limitations of taxation and distribution of benefits was opened up as appropriate, and several rather concrete and clear stipulations were made. This will serve as the first legal article in the area of administration of technology markets in Liaoning and will become an important basis for the formulation of managerial methods for technology markets.

Reporter: The goal of expansion in the decision-making rights of research organizations is to truly free up and invigorate research units. This is the starting point and home for reforms in research organs. Administrative departments should strengthen macro management and simplify management and relax authority. Truly opening up the gates of research units is a prerequisite condition for expanding decision-making rights. How do the "Certain Resolutions" take this into consideration?

Lin Sheng: Based on existing problems, the "Certain Resolutions" make a key proposal that scientific research units be given rights in five areas: the right to readjust the direction of scientific research, to transfer achievements, to appoint personnel, to hire and fire cadres and to give rewards and punishments. Some comrades are concerned over the right to readjust the direction of scientific research. Without such rights, it would be very difficult for scientific research units to orient toward society and to be unleashed and enlivened. There is no way that they will discard their own advantages and take up some other activity. Of course, regardless of the nature of their authority, they first of all must complete tasks assigned by the state.

In "expansion of the decision-making rights of research organs," the question of the allocation of bonuses in different types of scientific research units must be clarified.

Standards for allocation of bonuses can be divided into three categories: 1) In order to encourage units that receive administrative expenditures from the state to produce more achievements and more skilled people and to make more contributions to national economic construction, certain of the better units can, with approval by administrative departments, "relax bonus allocation standards to the average standard wage for 2 months." This takes into consideration the differences between the situation in research units and in party and government organs, and it also considers the need to avoid the appearance of great disparities in bonuses between different research units. Continued allocations of administrative expenditures to units are determined by their research tasks and the direction of their services, and are needed for social development. This research is not indispensable and cannot be crippled. Thus, this type of decision was made concerning bonuses for personnel engaged in research in this area. 2) Units with gradually reduced administrative expenditures are a transitional state in the reforms. The stipulations point

out "besides permission to allocate bonuses of one-half an average month's wages, each 10 percent reduction in annual administrative expenditure standards can have an additional 2 percent deducted from the net income of the unit to serve as bonus expenditures." This links up the amount of reduction in administrative expenditures and bonuses within a unit. The goal is to encourage the achievement of economic independence as soon as possible. When average per capita yearly bonuses allocated in this manner exceed 2 and one-half months' standard wages, taxes should be collected as stipulated. 3) For research units that are completely independent economically, the "Resolutions" of the CPC Central Committee point out clearly that "they can, as determined by the State Council, have the right to allocate bonuses from their own enterprise expenditures and to reform wages." State bonus and wage policies for enterprise employees can be dealt with on the basis of two general situations. The first is in large and medium-sized enterprises, which can implement a method of floating total wage bills and amount of taxes paid to higher authorities. The second situation is in small state-run enterprises, which implement ownership by the whole people, collective management and responsibility for their own profits and losses. After payment of sufficient taxes to the state and retention of production and development funds, they can make their own decisions on distribution. Based on the different sizes of research units, the "Certain Resolutions" also underline that after research units with administrative expenditures under 200,000 yuan or net incomes not in excess of 200,000 yuan attain economic independence, they can be dealt with according to the methods used for small state-run enterprises. If they surpass this level, they are treated as large and medium-scale enterprises.

In consideration of the actual situation facing wage reforms in state organs and enterprise units this year, reforms in research units that already have attained economic independence last year should be treated as enterprise units and participate in this year's wage readjustments and reforms. After economically independent research units readjust wages, total increases in wages are to be taken out of their own capital.

Reporter: A stronger ability of enterprises to absorb and develop are an important question in the "Resolutions." How do the "Certain Resolutions" implement the decisions of the CPC Central Committee?

Lin Sheng: Enterprises are the largest buyers of technical achievements. A weak ability to absorb and develop new technologies on their part not only affects development of the enterprises themselves but also influences the development of S&T. In the "Resolutions" of the CPC Central Committee, a stronger ability of enterprises to absorb and develop is achieved on the one hand through encouragement of associations and cooperation between scientific research units and institutions of higher learning and enterprises to establish and develop scientific research and production associations in order to strengthen the ability of enterprises to absorb and develop technologies. This point has been proven through experience in China and abroad. Following a conference on technical cooperation and economic associations for all areas of Liaoning was convened in July 1983 in Fuxin City, 9 cities and 5 counties already had held technical cooperation discussions by the end of 1984 and they

invited more than 5,600 experts, professors and technical personnel from more than 20 provinces and municipalities in China for technical cooperation with enterprises and joint attacks on key problems and development of new products. On the basis of technical cooperation, several hundred now have developed into long-term comprehensive cooperation scientific research and production associations.

Another area is to encourage enterprises to look within and organize their own forces to focus on scientific research units and technical development work. In 1983, the Liaoning Provincial government put forth a call stating that "large-scale enterprises should establish research institutes or technical development centers, medium-scale enterprises should establish research institutes or research offices and small-scale enterprises should establish research offices or research groups." The current "Certain Resolutions" call for independent decision-making rights in factory-run research organs. The reason is that management systems within enterprises should carry out the corresponding reforms based on the need for reforms in economic systems. We propose that enterprises implement a management method of "centralized policy-making, two-level administration, independent accounting and independent responsibility for losses or profits" in research organs under their jurisdiction to give even greater decision-making rights to research organs. This will benefit the strengthening and development of factory-run research organs.

The "Certain Resolutions" also make corresponding stipulations for administrative expenditures on scientific research and technical development in enterprises. We believe that scientific research and technical development will be strengthened to a substantial extent after these measures are implemented.

Reporter: Comrade Xiaoping has said that "the main thing and the thing that I am most concerned with in reforms of economic systems is personnel. In reforms of S&T systems, I still am most concerned with personnel." How do the "Certain Resolutions" understand this problem?

Lin Sheng: Liaoning Province contains units of the CPC Central Committee assigned to our province that now have 800,000 specialized personnel. This is a substantial number in terms of China as a whole, but they are very unevenly distributed at present and there is a serious problem of overstockage and waste. If we deduct the specialized personnel in CPC Central Committee units, Liaoning does not have very many specialized personnel. According to statistics for 1983, Liaoning as a whole had 540,000 specialized personnel, equal to 7.2 percent of the province's total employees [in the state-run sector]. This was ninth nationwide and lower than the national level of 10.3 percent. Among these personnel, their distribution, structure and specialization structures are very ill-suited to economic development. By 1990, Liaoning will have a natural personnel decrease of 70,800 people, including an 80 percent natural decrease in the highest level of technical personnel, meaning that there will be an even more serious shortage of skilled people. Most specialized personnel are concentrated in large-scale factory and mining enterprises, in institutions of higher learning and in scientific research units. There is a shortage of specialized personnel in light industry, agriculture and especially in collective enterprises. There are only 21 engineering and technical personnel among the 200,000 employees in urban and township enterprises in Dalian City, equal to only 0.1 percent of the employees. This type of situation tells us that we must reform personnel administration systems, and that

we especially need to encourage rational circulation of skilled people. Personnel circulation is very difficult at the present time, however, and there has been no basic breakthrough in the situation of stagnation in the same place. In implementing these "Resolutions" of the CPC Central Committee and reforming S&T systems, we feel that this remains an important matter that must be focused on.

As for the question of encouraging rational circulation of personnel and making full use of S&T personnel, the state, the Liaoning CPC Committee and the provincial government have made some decisions, but the time involved is short, so this draft of the "Certain Resolutions" is based only on the current situation that has appeared in personnel circulation to make some supplementary stipulations.

One is that we should adhere to rational circulation of personnel and encourage S&T personnel to go to regions with rather arduous living conditions and urgent development needs, and they can be given preferential wage and welfare treatment. The current question that has appeared in personnel circulation is that we must not be alarmed but should deal with it properly.

The second is to emphasize the circulation of knowledge. Because S&T personnel are the creators as well as the carriers of knowledge and technology, this sort of circulation does not require a transfer of residence permits, movement of dependents or readjustment of personnel relationships. It can be accomplished easily given China's current situation by using technical cooperation, technical advisory services and other forms. Practice has proven that this is a good method for exploiting the talents and intellect of personnel and an excellent pattern for making full use of existing S&T personnel.

The third is to implement fixed assignments and fixed personnel in units where there are relative concentrations of S&T personnel and gradually implement a recruitment system. A recruitment or appointment system for specialized positions is an important reform in specialized personnel management work. Specialized positions involve the allocation of job positions according to actual needs and with clear responsibilities. There are certain written restrictions on the numbers involved and specific periods of assignment. Generally speaking, under a recruiting system for specialized positions, S&T personnel who cannot take up positions in their own units or departments because the limits have already been filled should move to take up posts in other units or departments. This will promote rational circulation of talented people and scholarly exchanges and it will permit achievement of a recruiting system for specialized positions. Most recently, the state has come up with some trial methods and now is preparing to try them out. They will be extended gradually after experience has been gained.

Many management questions still remain for S&T personnel in the province and cities and they should be managed well together in the future. Arbitration organizations for personnel circulation also should be established to deal with contradictions and disputes in personnel circulation.

NATIONAL DEVELOPMENTS

S&T SYSTEM REFORM DEVELOPMENT MEASURES FORMULATED

Beijing JISHU SHICHANG BAO [TECHNOLOGY MARKET WEEKLY] in Chinese 2 Jul 85 p 1

[Article: "Eliminate Obstacles, Promote Actively S&T System Reform; Some Areas, Departments Formulate Development Measures"]

[Text] Since the "CPC Central Committee Resolution on S&T System Reform" was published, great progress has been made in S&T system reform in all areas throughout China. Various provinces, municipalities and autonomous regions such as Sichuan, Shanxi, Hubei, Gansu, Liaoning, Hebei, Yunnan, Anhui, Guangdong, Heilongjiang, Ningxia, Jiangxi and Beijing and various State Council ministries such as the Ministry of Machine-Building Industry, the Ministry of Metallurgical Industry, the Ministry of Posts and Telecommunications and the Ministry of Coal Industry have by now held separate S&T work conferences. Some areas and departments are preparing actively to hold S&T work conferences in the near future. Based on their actual conditions, many areas and departments have studied the "Resolution" conscientiously, integrated their knowledge and proposed specific measures to carry it out. These measures are not "official" or "stereotyped," but are ones which the masses can see, feel and understand the actual effects of.

The first of the development measures and plans which have been proposed by various areas is preparing actively to reform the operating expenses allocation system for development research organizations. For instance, Hubei, Hebei, Liaoning, Shanxi, Gansu and the Ministry of Machine-Building Industry have proposed separately to change within 2-5 years from allocating operating expenses to carrying out a contract fulfillment system. The second is creating the conditions to develop vigorously technology markets. Provinces such as Hebei have proposed that, in addition to holding provincial S&T business conferences, localities, cities and counties must also hold them. Hebei Province has also organized 10,000 technicians to go to small- and medium-sized enterprises and rural areas to develop technical advisory services. Hubei Province and the city of Wuhan have provided 4 million yuan to build a large technology market building. The third is increasing the fund allocation for three S&T projects. Liaoning Province has proposed beginning in 1986 to increase S&T funds 2.5 million yuan a year, Gansu Province will increase allocation 3-5 percent a year more than local revenue and Shanxi's Industrial-Commercial Bank will give preferential tax rates for S&T loans, reaching over 2 million yuan a year during the period of the "Seventh 5-year plan." The fourth is proposing mea-

measures to improve conscientiously the living conditions of scientists and technicians. In 1985, Beijing Municipality has allocated a special fund to build 50,000 square meters of living space in order to alleviate the housing problems of its intellectuals. Gansu Province has provided 3 million yuan a year to improve the living and working conditions of its scientists and technicians. Faced with present conditions in the industry, the Ministry of Coal Industry has carried out special policies for scientists and technicians and given grade-1 fluctuating wages to college students who are newly assigned to engage in above-ground work, grade-2 fluctuating wages to those who work underground and service subsidies to currently employed workers based on their years of service in the coal industry. The fifth is using various measures to promote technical reforms in agriculture. It is reported that an existing problem in present S&T system reform is that work developments are imbalanced between areas and between departments and some have not yet taken efficient measures, resulting in the appearance of reform problems which have been unable to be solved promptly and causing the masses to consider reform "unattainable." A present problem which particular attention should be paid to solving is the need to strictly distinguish the limits between S&T system reform and unhealthy tendencies, eliminating obstacles and promoting the successful accomplishment of reform.

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NATIONAL DEVELOPMENTS

NINGXIA INSTITUTE TRANSFORMS S&T RESULTS INTO PRODUCTIVE FORCES

Yinchuan NINGXIA RIBAO in Chinese 10 Jul 85 p 1

[Article by Xiong Dizhu [3574 4574 3137]: "Ningxia Hui Autonomous Region Light Industry Design Research Institute Opens Technical Market, Accelerates Process of Transforming S&T Results into Productive Forces"]

[Text] Since the Ningxia Hui Autonomous Region Light Industry Design Research Institute has made the breakthrough of opening a technical market and carried out comprehensive reforms, an unprecedented vitality has appeared throughout the institute during the past half year. Scientists and technicians are moving one after another from laboratories to all mountain and river areas and town and country enterprises and many scientific research results are being transformed into productive forces and beginning to achieve quite good economic and social results.

The research institute leadership has carried out reforms according to the strategic principle that S&T must be geared to the needs of economic construction. At the beginning of 1985, they improved first the leadership system and expanded its initiative; based on simplifying the organization and reducing the number of personnel, the functional administrative offices carried out a personnel advertisement system; based on reducing separately a specific proportion of the operating expenses of certain subordinate departments, basic level departments carried out economic business accounting so that the whole research institute would be able to gradually support itself. In addition to ensuring the fulfillment of state assigned scientific research tasks and faced principally with Ningxia's textile industry production conditions, all scientific research laboratory departments have developed adaptable technology, carried out S&T development contracts and a job responsibility system and formulated economic targets which create social value through measures such as transferring S&T results and providing technical service and advice in order to replace comprehensive rewards with results rewards. This series of reforms has spurred all research laboratory and scientific research personnel to take the initiative in serving economic construction and enabled S&T to be combined with economic and social development.

In order to enable S&T results to be transformed into commodities and to improve economic results, the research institute has geared itself to the pressing need for technology of enterprises in all mountain and river counties, townships

and villages and developed actively its technical service, technical advice and technology transfer work. By the end of May 1985, it had signed 51 agreements and contracts with a total volume of business of over 304,800 yuan. For instance, it has invested technology in three related jointly run enterprises, the Yinchuan Chemical Plant, the Qingtongxia Municipal Household Electrical Appliance Plant and the Pingluo County Hemp Plant, all of which have used fully the research institute's advanced scientific research results, improved their technology and product quality and developed markets for new products which are in great demand. All of these jointly run enterprises have research institute technicians as assistant plant managers and this has both alleviated the problem of the enterprises lacking qualified technicians and will also be able to train for China a group of qualified business type technicians who understand both S&T and management. The research institute has relied on the enterprises to expand quickly its intermediate experimental base and accelerate the process of transforming S&T results into productive forces.

Most of the over 140 scientists and technicians in the Ningxia Hui Autonomous Region Light Industry Design Research Institute have now aligned themselves with fulfilling social needs and serving actively production units. The income from the transfer of technology throughout the institute during the first half of 1985 has increased 100 percent over that of all of 1984.

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NATIONAL DEVELOPMENTS

HUBEI MANAGEMENT, USE OF SCIENTISTS, TECHNICIANS REPORTED

Wuhan HUBEI RIBAO in Chinese 29 Jun 85 p 2

[Article: "Hubei Science and Technology Commission Chairman Liang Jiahui Reports on Management and Use of Scientists and Technicians at the 15th Meeting of the 6th Hubei Provincial People's Congress Standing Committee"]

[Text] Hubei Science and Technology Commission chairman Liang Jiahui [2733 0857 0583] reported on the management and use of scientists and technicians throughout Hubei to the 15th meeting of the 6th Hubei Provincial People's Congress standing committee on 25 June 1985.

He said that there have been three large-scale inspections throughout Hubei since 1982 of the implementation of policy on intellectuals, many misjudged cases left over by history have been redressed, and based on this, governments at all levels have stressed the following tasks which have been favorable to arousing fully the enthusiasm of the masses of scientists and technicians: revising the use of personnel in positions which do not suit their specialties; evaluating technical titles; improving intellectuals' working and living conditions; implementing basic medical treatment and health care for senior intellectuals above the grade-6 national skill level; giving mountain area subsidies and fluctuating grade-1 wages to scientists and technicians who work in remote mountain areas and frontline agriculture and giving rewards of preferential promotions and wage scales to some outstanding young and middle-aged S&T experts; choosing a group of intellectuals to assume leading posts at all levels based on the requirements of the "four modernizations."

In order to arouse further the enthusiasm of the masses of scientists and technicians and promote the development of all of Hubei Province's reform work and economic construction, the provincial party committee and the provincial government also formulated successively during the last half of 1984 "Provisions on Implementing Further Certain Problems of Policy on Intellectuals" and "Certain Views on Respecting Knowledge and Qualified Personnel and Using as Quickly as Possible a Generation of People of a New Type," which governments at all levels are carrying out conscientiously. Liang Jiahui said that, adapting to the needs of economic construction and S&T development, Hubei Province's S&T management departments at all levels have reformed boldly the S&T cadre management system, circulated rationally scientists and technicians, tried the management system of personnel units making appointments from within and

and inviting job applications from without and found out and summarized conscientiously experience in circulating qualified personnel. They have also strengthened foreign S&T exchange activity, imported actively qualified personnel from abroad and sent scientists and technicians abroad to engage in advanced studies, observe and study or attend international conferences.

In his report, Liang Jiahui also discussed the problems of strengthening continuing education, improving the quality of scientists and technicians, reforming the S&T cadre management system and establishing and perfecting S&T cadre management organizations at all levels.

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CSO: 4008/2021

NATIONAL DEVELOPMENTS

UNIVERSITY OF SCIENCE AND TECHNOLOGY EDUCATIONAL REFORMS

Hefei ANHUI RIBAO in Chinese 4 Jun 85 p 1

/Article: "Focus on Basic Education, Encourage Excellence in Study--Over 80 Percent of the Undergraduate Students Graduating From the Chinese University of Science Are Admitted as Graduate Students"

/Text/ The Chinese University of Science and Technology has been active in carrying out educational reforms. It has combined the strengthening of basic education with allowing students to receive preliminary training in scientific research work while they are enrolled. This has been effective in raising the quality of students. Some 60 percent of the first three classes of undergraduate students who entered school after 1977 passed examinations for graduate study. More than 80 percent of this year's undergraduate class has passed graduate student exams and the figure reached 94 percent in certain departments. Many students now are competing in graduate student testing in research institutes under the Chinese Academy of Sciences.

The Chinese University of Science and Technology always has made the training of high-quality S&T personnel its goal of struggle. They have concentrated on basic education to train students in the ability to think independently, to analyze problems and to solve problems. Following the restoration of the system of college and university examinations in 1977, the schools quickly restored and re-established basic educational facilities for the schools as a whole, and they selected teachers in basic education who had high scholarly levels and rich teaching experience. In educational management, the schools permitted students, with a strong ability to learn, to suggest upperclass study curricula and to select for education in specific skills and permitted the students being tutored who made superior achievements to sit at an earlier date for examinations to graduate study.

The Chinese University of Science and Technology has been resolute in implementation of the unique school administration method of "having the entire academy run schools, integrating institutes and departments," and it has focused on training the creative abilities of students. Leaders and many famous scientists in the colleges and institutes under the Chinese Academy of Sciences have taken up joint posts and teaching appointments in schools and they are engaged in cooperative research. This has opened up relationships between research institutes and schools, and it has enriched teaching curricula and improved

scholarly levels. About 200 experts and teachers have taken up joint posts in schools and upperclass students often participate in research work in the research institutes. This educational system that integrates institutes and departments places students in contact with the forefront of their discipline while they are enrolled and it has given them real training in scientific research work.

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CSO: 4008/393

NATIONAL DEVELOPMENTS

BRIEFS

FANG YI ATTENDS RARE EARTH SEMINAR--Beijing, 14 Sep (XINHUA)--State Councilor Fang Yi met here today with a group of foreign experts attending an international conference on rare earth development and applications. The experts, from 21 countries, also participated in an international fair for rare earths and their application products now being held in Beijing. Among those present at the meeting were Chinese Vice-minister of the State Economic Commission Yuan Baohua and President of the Chinese Rare Earth Society Zhou Chuandian. [Text] [Beijing XINHUA in English 1513 GMT 14 Sep 85 OW]

NATIONAL MEETING ON PATENTS--Dalian, 16 Aug (XINHUA)--The first 50 to 60 patent applications classified and examined by China's new patent office, will be published in September, according to a national meeting on patents which is in session here. They will be approved by the end of this year. By the end of July, China's Patent Bureau had received 8,400 applications. The country's first patent law was put into effect on April 1. The total volume of applications for patent rights is expected to reach 12,000 to 15,000 by the end of this year. About one third of the applications received came from 30 countries and regions including Japan, the United States, Federal Germany, the Netherlands, Britain, Switzerland and Hong Kong. At present, China has 4,400 licensed patent agents and another 1,500 are being trained. [Text] [Beijing XINHUA in English 1042 GMT 16 Aug 85 OW]

CSO: 4020/350

## PHYSICAL SCIENCES

## NEW CRITERION OF COMBINED-MODE BRITTLE FRACTURE DESCRIBED

Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 5, No 6, Nov 84 pp 849-853

[Article by Lin Baisong [2651 2157 2646], Central South Mining and Metallurgical Institute: "The Circumferential Stress-Strain Product Criterion in Combined-Mode Brittle Fracture"\*; paper received 9 September 1983]

[Text] ABSTRACT: A new mixed-mode brittle fracture criterion, the circumferential stress-strain product, is presented. It is found to be in good agreement with experimental data.

## I. Introduction

Several investigators [1-6] have recently obtained combined-mode brittle fracture criteria expressed in terms of the stress intensity factors  $K_I$  and  $K_{II}$ ; these criteria are all contained in the following empirical criterion proposed by the present author:

$$(K_I/K_{Ic})^m + (K_{II}/K_{IIc})^n = 1 \quad (1 \leq \frac{m}{n} \leq 2) \quad (1)$$

Based on a combined study of strain energy density criteria [7], the maximum circumferential stress criterion [8] and the maximum circumferential strain criterion [9], we propose a new criterion, i.e., the circumferential stress-strain product. In the case of a one-dimensional stretching of a plate with a central oblique crack, for a planar stress state with  $\mu = 1/3$  or a planar strain state with  $\mu = 0.25$ , the maximum circumferential stress-strain product criterion has the formula of  $K_I/K_{Ic} + (K_{II}/K_{IIc})^2 = 1$ . This indicates that this criterion is in extremely good agreement with the experimental data.

## II. The Circumferential Stress-Strain Product Criterion

The stress components  $\sigma_r$ ,  $\sigma_\theta$  and  $\tau_{r\theta}$  in the vicinity of the tip of the I-II combined-mode crack shown in Figure 1 are:

\*Recommended by Qian Weichang [6929 0251 7022].

$$\left. \begin{aligned} \sigma_r &= \frac{1}{2\sqrt{2\pi r}} \left[ K_I (3 - \cos\theta) \cos \frac{\theta}{2} + K_{II} (3 \cos\theta - 1) \sin \frac{\theta}{2} \right] \\ \sigma_\theta &= \frac{1}{2\sqrt{2\pi r}} \left[ K_I (1 + \cos\theta) \cos \frac{\theta}{2} - K_{II} (3 \sin\theta) \cos \frac{\theta}{2} \right] \\ \tau_{r\theta} &= \frac{1}{2\sqrt{2\pi r}} \left[ K_I \sin\theta \cos \frac{\theta}{2} + K_{II} (3 \cos\theta - 1) \cos \frac{\theta}{2} \right] \end{aligned} \right\} \quad (2.1)$$

and the circumferential stress-strain product is:

$$P = \sigma_\theta \cdot \varepsilon_\theta = \frac{1}{E} (\nu_\theta^2 - \mu \sigma_r \sigma_\theta) \quad (2.2)$$

where E is the elastic modulus and  $\mu$  is the Poisson ratio. Substituting  $\sigma_r$  and  $\sigma_\theta$  from equation (2.1) into equation (2.2), we obtain:

$$P = \frac{1}{r} (A_{11} K_I^2 + 2A_{12} K_I K_{II} + A_{22} K_{II}^2) \quad (2.3)$$

where the coefficients  $A_{ij}$  ( $i, j = 1, 2$ ), are defined as:

$$\left. \begin{aligned} A_{11} &= \frac{1}{16\pi G} \left[ \cos^4 \left( \frac{\theta}{2} \right) (\kappa - 2 + \cos\theta) \right] \\ A_{12} &= \frac{1}{16\pi G} \left[ \frac{1}{2} \sin\theta \cos^3 \left( \frac{\theta}{2} \right) (3 - 2\kappa - 3 \cos\theta) \right] \\ A_{22} &= \frac{1}{16\pi G} \left[ \frac{3}{4} \sin^2\theta (\kappa + 3 \cos\theta) \right] \end{aligned} \right\} \quad (2.4)$$

Here,  $\kappa = 3 - 4\mu$  (planar strain) and  $\kappa = (3 - \mu)/(1 + \mu)$  (planar stress), and G is the shear elastic modulus.

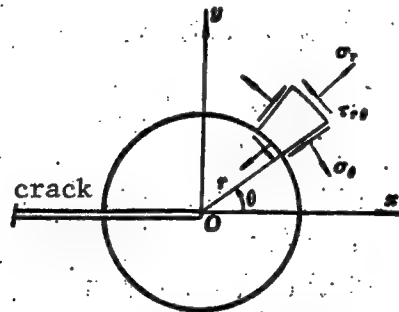


Figure 1. Stress components in plane polar coordinates

It follows from equation (2.3) that the circumferential stress-strain product has a singularity of order  $r^{-1}$ . We express the singularity intensity of the circumferential stress-strain product as  $L_\theta$ , which we call the circumferential stress-strain product factor, i.e.

$$L_0 = A_{11}K_I^2 + 2A_{12}K_I K_{II} + A_{22}K_{II}^2 \quad (2.5)$$

This factor is related to  $\theta$  through coefficients  $A_{ij}$ .

Regarding the circumferential stress-strain product criterion, we note the following:

1) The crack begins to expand in the direction in which  $L_0$  has its maximum. Therefore, the formula for determining the crack opening angle  $\theta_0$  is:

$$\frac{\partial L_0}{\partial \theta} = 0, \quad \frac{\partial^2 L_0}{\partial \theta^2} < 0, \quad \text{for } \theta = \theta_0 \quad (2.6)$$

2) When the maximum value of the circumferential stress-strain product factor reaches the critical value  $L_{0cr}$ , the crack begins to expand. Therefore, the condition for the beginning of crack expansion is:

$$L_{0max} = L_{0cr} \quad (2.7)$$

Obviously, when  $\mu = 0$  the circumferential stress-strain product criterion is a criterion for maximum circumferential stress or maximum circumferential strain.

### III. Crack Opening Angle

We now determine the crack opening angles for type I and type II cracks and type I-II combined-mode cracks.

#### 1) Type I Cracks

For mode I cracks we have

$$L_0 = A_{11}K_I^2 \quad (3.1)$$

Substituting this into equation (2.6), we obtain the crack opening angle:

$$\theta_0 = 0 \quad (3.2)$$

Therefore the maximum value of  $L_0$  is:

$$L_{0max} = \frac{K_I^2}{8\pi G} (\kappa - 1) \quad (3.3)$$

#### 2) Mode II Cracks

For mode II cracks, we have

$$L_0 = A_{22}K_{II}^2 \quad (3.4)$$

Substituting equation (3.4) into equation (2.6), we obtain the equation for the crack opening angle  $\theta_0$ :

$$-\theta_0 = \cos^{-1} \left[ -\frac{\mu}{3} + \sqrt{\left(\frac{\mu}{3}\right)^2 + \frac{1}{3}} \right] \quad (3.5)$$

and the maximum value of  $L_\theta$  is:

$$L_{\max} = A_{22}(\theta_0) K_I^2 \quad (3.6)$$

An example of the calculation of  $-\theta_0$  is shown in Table 1. For graphite samarium ( $\perp$ ) with  $\mu = 0.07$  and graphite 7477 with  $\mu = 0.2$ , the average actual crack opening angle for mode II fracture is  $67^\circ$  [3], indicating that the criterion is in extremely good agreement with measurements.

Table 1  $-\theta_0$  Values

Poisson ratio $\mu$		0	0.1	0.2	0.25	0.3	$\frac{1}{3}$	0.4
$-\theta_0$	a 平面应力	70.5°	69.25°	68.05°	67.5°	67°	66.65°	66°
	b 平面应变	70.5°	69.1°	67.5°	66.65°	65.7°	65.1°	63.75°

a=Planar stress; b=Planar strain

### 3) Central Oblique Crack

For one-dimensional elongation of a central oblique crack, the stress intensity factor is:

$$K_I = \sigma \sqrt{\pi a} \sin^2 \beta, \quad K_{II} = \sigma \sqrt{\pi a} \sin \beta \cos \beta \quad (3.7)$$

where  $\sigma$  is the tensile stress,  $a$  is the crack half-length, and  $\beta$  is the crack angle.

Substituting equation (3.7) into equation (2.6), we obtain the following equations for the crack opening angle  $\theta_0$ :

$$\left( \frac{\partial A_{11}}{\partial \theta} \right)_{\theta=\theta_0} + 2 \left( \frac{\partial A_{12}}{\partial \theta} \right)_{\theta=\theta_0} \cdot \operatorname{ctg} \beta + \left( \frac{\partial A_{22}}{\partial \theta} \right)_{\theta=\theta_0} \cdot \operatorname{ctg}^2 \beta = 0 \quad (3.8)$$

Calculated values for the opening angle  $\theta_0$  corresponding to various crack angles  $\beta$  for  $\mu = 1/3$  are shown in Table 2, which also gives actual crack opening angles. It is evident from the table that the discrepancy between the theoretical and measured crack opening angles is small.

Obviously the maximum value of  $L_\theta$  is:

$$L_{\max} = A_{11}(\theta_0) K_I^2 + 2 A_{12}(\theta_0) K_I K_{II} + A_{22}(\theta_0) K_{II}^2 \quad (3.9)$$

Table 2 Relationship between  $-\theta_0$  &  $\beta$  for  $\mu = \frac{1}{3}$

$\beta$		30°	40°	50°	60°	70°	80°
$(-\theta_0)$	a 实验值	62.4°	56.6°	51.6°	43.1°	30.7°	17.3°
	b 理论值	57.5°	52.9°	50.2°	43.5°	32.7°	18.8°

a=Experimental values; b=Theoretical values

#### IV. Combined-Mode Brittle Fracture Criterion

Below we determine  $K_{IIc}$  and the combined-mode brittle fracture criterion.

##### 1) Mode I Cracks

From equations (2.7) and (3.3) we determine the critical value of  $L_0$ :

$$L_{cr} = \frac{1}{8\pi G} (\kappa - 1) K_{Ic} \quad (4.1)$$

where  $\kappa = 3 - 4\mu$  and  $K_{Ic}$  is the failure toughness for planar strain.

##### 2) Mode II Cracks

The condition for opening of a mode II crack is:

$$\frac{K_{IIc}}{16\pi G} \left[ \frac{3}{4} \sin^2 \theta_0 (\kappa + 3 \cos \theta_0) \right] = \frac{\kappa - 1}{8\pi G} K_{Ic} \quad (4.2)$$

Substituting the value of  $\mu$  from Table 1 and the corresponding crack opening angle  $\theta_0$  into equation (4.2), we obtain the ratio  $K_{IIc}/K_{Ic}$ . The calculated values of this ratio are shown in Table 3.

Table 3  $K_{IIc}/K_{Ic} - \mu$  relationship

Poisson ratio $\mu$		0	0.1	0.2	0.25	0.3	$\frac{1}{3}$	0.4
$\frac{K_{IIc}}{K_{Ic}}$	a 平面应力	0.866	0.821	0.774	0.748	0.722	0.705	0.687
	b 平面应变	0.866	0.816	0.748	0.706	0.660	0.607	0.494

a= Planar stress; b=Planar strain

It is evident from the table that: (1) the value of  $K_{IIc}/K_{Ic}$  increases as  $\mu$  increases; (2) the value of  $K_{IIc}/K_{Ic} = 0.63$  predicted in Ref. 10 is close to the value of  $K_{IIc}/K_{Ic} = 0.65$  for planar strain when  $\mu = 0.3$  in our criterion; (3) the value of  $K_{IIc}/K_{Ic} = 0.724$  predicted in Ref. 11 is almost identical to the value of  $K_{IIc}/K_{Ic} = 0.722$  for planar strain with  $\mu = 0.3$ ; (4) it is pointed out in Ref. 9 that the average measured value of the ratio  $K_{IIc}/K_{Ic}$  for a plexiglass sheet is close to 0.737 or 0.652, indicating extremely good agreement between the present criterion and measured values.

### 3) Central Oblique Cracks

For one-directional elongation of central oblique cracks, we substitute equations (3.9) and (4.1) into equation (2.7), obtaining the crack opening condition:

$$A_{11}(\theta_0)K_I^2 + 2A_{12}(\theta_0)K_I K_{II} + A_{22}(\theta_0)K_{II}^2 = \frac{\kappa-1}{8\pi G} K_{Ic}^2 \quad (4.3)$$

We can use this equation to calculate the values of  $K_I/K_{Ic}$  and  $K_{II}/K_{IIc}$  for crack opening. For planar stress with  $\mu = 1/3$  and planar strain with  $\mu = 0.25$ , the calculated values of  $K_I/K_{Ic}$  and  $K_{II}/K_{IIc}$  are shown in Table 4.

Table 4  $K_I/K_{Ic}$  &  $K_{II}/K_{IIc}$  values

$\beta$	0°	30°	40°	50°	60°	70°	80°	90°
$-\theta_0$		57.3°	52.9°	50.2°	48.5°	32.7°	18.8°	0°
$K_I/K_{Ic}$	0	0.333	0.441	0.559	0.686	0.814	0.943	1
$K_{II}/K_{IIc}$	1	0.820	0.748	0.664	0.561	0.423	0.243	0

After calculations, we obtain

$$\frac{K_I}{K_{Ic}} + \left(\frac{K_{II}}{K_{IIc}}\right)^2 = 1 \quad (4.4)$$

This is Wu's empirical criterion [2] and Lee et al.'s theoretical criterion [4]. Thus our criterion is in extremely good agreement with the experimental data.

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CARTOGRAPHY, NATIONAL LAND MANAGEMENT RELATED

Beijing RENMIN RIBAO in Chinese 16 May 84 p 5

[Article by Shao Wenxiang [6730 2429 4382]: "Surveying, Cartography and National Land Management"]

[Text] The practice of surveying and cartography provides one of the indispensable and fundamental preliminary task for national land management. As a matter of fact, the success of national land management is closely related to the performance of the surveying and cartography service. The development of national land management requires a thorough preliminary inventory of geographical conditions and the natural and human resources in the territory; the surveying and cartography process is one of the important means to obtain this type of information. Land management is based on the results and maps produced by the surveying and cartography service. Nearly all the land management tasks, such as land planning and management, utilization, protection and administration, require the information acquired by surveying and cartography.

Maps are one of the major final products from the surveying and cartographic processes. They are frequently used in land management. The most important piece of data for calculating land areas precisely, including total territories, areas of various administrative districts and areas of different types of lands such as farmland, forests, pastures, deserts, residential land and highway networks, inland rivers, lakes and watery regions, shore lands, jungles and icebergs and glaciers as well as other uncultivable lands, is the scaled map prepared by the surveying and cartography service.

A good example is the total area of farmland in China, which has never been determined accurately. The high-precision maps as well as the area data thus derived from them become the essential scientific information in agriculture policy-making. We can only make map studies and highlight the results so obtained on maps in order to compile thematic agricultural maps on different scales for specific purposes, such as land utilization maps, land classification maps, land condition maps and soil distribution maps, so as to be able to provide agricultural planning and arrange some reliable data and information.

The development, utilization, protection and management of forests, water power, coal, wilderness and mines as well as urban and suburban planning and

transportation construction require the support of surveying and cartography. For instance, the basic equipment for conducting general surveys, explorations and other related studies of geological resources is the map.

A prerequisite for a labor resources study is the census. Based on the census results, thematic maps on population, including population distribution maps, population density maps, population composition maps and nationalities distribution maps can be compiled and then used in national economic planning.

With the progress of the four modernizations, there will be an increasing need for regional studies of a general survey nature. For example, the general survey of the Qinghai-Xizang highlands, the general survey of oceanic resources in the South China Sea. The investigation of the glacier and frozen lands of the Northwest Plain and the investigation of the wilderness on the Sanjiang Plain are based to a great degree upon the information and maps furnished by the surveying and cartography services.

In short, surveying and cartography play very important roles in national land management. It is difficult for research reports and papers, well prepared as they may be, to convey their messages as effectively as the maps which present the results of the surveying and cartographic processes in a complete, accurate and straightforward manner and enable readers to understand fully, at a glance, of the natural geographic conditions and human economic activities as well as their interrelationship.

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APPLIED SCIENCES

BENEFITS OF SURVEYING, CARTOGRAPHY DESCRIBED

Beijing RENMIN RIBAO in Chinese 16 May 84 p 5

[Article by Yu Cang [0827 3318], deputy director of the State Surveying Bureau: "Surveying and Cartography Should Create Conditions for Improving Economic Construction"]

[Text] Surveying and cartography are two important methods for investigating nature and studying societies. They are considered to be the fundamental preparations and the preliminary procedures to a national economic development program. The basic functions of surveying and cartography include the determination of precise geographic coordinates, altitude and gravity data for all the control points in our territory and the publication of maps at various scales of China, thematic maps and map collections as well as surveying and mapping services for economic development, national defense construction, cultural education, scientific research, foreign affairs, border-area surveying, transportation, tourism and interior administration. In addition, performance of these tasks such as agricultural resource investigation and zoning, farmland water conservancy development, geological studies and mining surveys, the exploration and utilization of geothermal power, exploration of oil and coal fields, route surveying and the construction of railways and highways, hydrographic surveying and river control, earthquake prediction and advance warning, shoreline resource study and urban planning requires reliable survey data and maps provided by preliminary surveying and cartography services.

Surveying and cartography exert direct effects on the scientific planning of the construction project and its execution as well as the realization of planned utilities. Nearly all the scientific research task involving geological studies require the use of survey data, maps and other related information. Today, there exists a pressing need, both in the fields of natural science and social science, to present results of thematic studies with the help of maps. Surveying and cartography provide terrain information and target data, especially geographic coordinates and orbital data for long-range weapons systems in modern warfare. Hence, surveying and cartography play important roles in our socialist modernization program.

In the 3 decades since the founding of the People's Republic, the mass of our survey workers has defied hardships and difficulties to perform a great deal

of essential tasks. Among their accomplishments are: location and surveying of hundreds of thousands of control points nationwide; the completion, for the first time, of the astronomical-level network-profile leveling of China; the location and surveying of a first-class roads of more than 90,000 km nationwide; the compilation of maps, mainly by aerial photogrammetry, covering the entire surface area of China (excluding Taiwan Province), on scales of 1:25,000, 1:50,000 and 1:100,000 as well as national reduction maps on scales of 1:200,000, 1:500,000 and 1:1,000,000. In addition, partial map revisions of second and even third generations have been made. Since the sixties, agricultural and industrial development area maps of 1:10,000 scale, covering no less than 1.8 square km have been prepared. Large number of maps on scales ranging from 1:5,000 to 1:500 or larger, designed for construction projects of agriculture, energy, transportation and urban development and other engineering surveys have been provided and conducted by specialized survey services. To meet the requirements of administrative authorities, the surveying and cartography service compiled and printed maps or volumes of maps of 1,800 districts, cities and counties; also published were general maps and thematic maps of more than 1,000 different categories, the total volume of which is close to 800 million. Since the 3d Plenary Session of the 11th Party Central Committee, sales of maps for public consumption have grown an average of 2.7 times a year.

Yet we are fully aware that what we have been able to achieve still falls far behind the demands of national development goals passed by the 12th Party National Congress and of the cultural life of our society with ever-rising living standards. This has been, in large measure, due to the fact that the services we can provide are rather limited, and are far exceeded by the users' demands; there exists a big gap. The real situation today expects us to double our efforts to accelerate the development of the surveying and cartography field and expand our services in newer and greater areas.

Our primary tasks in the 1980's geared to the needs of national development goals and strategic preparations before the end of this century, put forth by the 12th Party National Congress, therefore include: putting the service to good order and wiping out confusion by sound administration and management; preparing ourselves well by laying a solid foundation for cultivating professional talent and for advancing surveying and cartographic technologies so as to create favorable conditions for the development of surveying and cartography in the next decade; carrying out preliminary preparations for a development program to raise the nation's economy growth in all spheres; and striving to double, by 1990, the production of 1983 in terms of new map categories dedicated to development in key areas, important installations and expanded agricultural resources investigation services. In the next 10 years, the surveying and cartography service should redouble its effort to advance related technologies so as to shorten map preparation time and speed up map revision processes; to strive, by the end of this century to build a data bank to provide survey data and other information for territorial administration and natural resources development; to enlarge cadastral surveying for land administration; to expand beach, shore-line and off-shore island surveys for the development of oceans resources; to complete compiling, printing and revising the basic map of China and further enlarge the large map scales

expressly prepared for uses in economic development; and to increase the categories, improve the patterns and enrich the contents of maps openly published so as to satisfy the needs of the cultural life of an increasingly prosperous society.

In order to realize the foregoing growth goals, the surveying and cartography service must surmount hardships and difficulties to fulfill two critical assignments; to endeavor to broaden the practical horizon of our service and continuously expand service areas and to pursue technological improvements.

The expansion of the surveying and cartography service is urgently needed for the four modernizations and the cultural life of the people. The service as a whole should adjust to bring about full internal coordination and planned expansion; to work together to conduct services in a more efficient manner and develop new capabilities in the engineering surveying and cartography service areas and to spare no effort in carrying out service jobs for the key construction projects of the national long-range development plans; to pursue close-range photogrammetry surveying and precision engineering surveying capabilities; to provide services for environmental surveillance, natural resource surveys and geological studies by active employment of aerial-space remote-sensing photogrammetry and multispectral photogrammetry techniques; to furnish technical directions for agricultural resource and other related surveys; and to double our efforts to compile and publish general and thematic maps of a much wider scope and to augment available map categories with new variants so as to relieve the "shortage of maps" of our society at the earliest possible moment.

On the technological front, we should rise to meet the challenges presented by the technological revolution. Before the year 2000, we are aiming, through the active pursuit of technological advances and the introduction of modern, effective surveying and mapping technologies, to promote the utilization of aerial photogrammetry, remote sensing and computer technology together with data banks and digitized automatic plotting procedures as well as advanced map-printing technologies to establish appropriate proportions in the overall surveying and cartography process. With the modernization of data processing technology, the urgency individual economic departments attached to their requests for maps and thematic maps grows; they are asking that surveying and cartographic information be provided directly on digitized magnetic tapes of the third generation. Surveying and cartography have become basic, indispensable sources of information for information societies. To satisfy the demands of national economic development, the surveying and cartography service will invest great efforts to digitize acquired survey data and store them in data banks; thus, existing information and maps so stored can be retrieved to furnish the geographical foundation of specialized data banks to be set up by economic departments and to provide the basic components of the national information system for resources, the environment, the economy and the population. The establishment of basic territorial resources data bank, i.e., the survey and cartography data bank, should not be postponed any longer.

The practice of surveying and cartography provides one of the fundamental preparatory works for the socialist modernization program and acts as the advance detachment clearing the way for economic development projects. My fellow workers in the surveying and cartography field, we must inherit and exalt the revolutionary spirit of surmounting arduous hardships and great difficulties to march forward in the face of opposition, to continue to pursue new achievements, to develop our service toward broader dimensions, multi-typed productions, greater precision, digitization and automation and to make every endeavor to create conditions for economic development.

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APPLIED SCIENCES

STATUS, DEVELOPMENT OF POWER ULTRASONICS IN CHINA

Beijing YINGYONG SHENGXUE [APPLIED ACOUSTICS] in Chinese Vol 4, No 3, Jul 85  
pp 1-6

[Article by Zhang Fucheng [1728 4395 2052] and Cheng Cundi [4453 1317 1717] of  
the Shaanxi Normal University Applied Acoustics Research Institute]

[Text] Abstract: This article concerns power acoustics and refers mainly to  
the utilization of rather high ultrasonic energy for cleaning, processing,  
ultrasonic therapeutics, surgery and other purposes. The frequencies used  
generally range from 10 kHz to 60 kHz (some are 1 MHz or more) with acoustic  
intensities ranging from 0.X watts/cm<sup>2</sup> to several hundred watts/cm<sup>2</sup> (the figure  
is even higher for some special uses).

Research on power ultrasonics in China has a history of nearly 30 years.  
During the late 1950's, besides the development of rather large scale ultra-  
sonic equipment for use in scientific research, general power ultrasonics  
equipment was already on the market. Power ultrasonics now has permeated many  
important realms of national defense and the national economy, including  
machinery, electronics, semiconductors, metallurgy, chemical industry, energy  
resources, pharmaceutical, agriculture, atomic power, textiles, printing  
and dyeing, art and other industries. A power ultrasonics scientific research  
contingent now has begun to grow and it has solved a number of problems in  
production and technology. This is especially true of the obvious achievements  
that have been made for the state in recent years. Several tens of achieve-  
ments have received awards from provincial and municipal level departments  
and some have received awards from the central and state levels. Production  
capacity now has attained a certain scale. About 4,000 pieces of equipment  
with an annual value of output of more than 30 million yuan can be supplied to  
the market each year. Not only is the equipment in use being gradually syste-  
matized, but some special equipment as well as semi-automated and automated  
equipment now continues to come on the market.

International scholarly exchanges also continue to develop. Almost 10 articles  
have been submitted for participation in international scholarly exchanges in  
recent years and some have received attention and good evaluations from foreign  
colleagues. Research on power ultrasonics in China now has joined the inter-  
national ranks.

Below, we would like to describe the current situation and development in power ultrasonics in China in the three areas of basic research on power ultrasonics, equipment development and production, and applications of power ultrasonics and their role in national economic construction.

## I. Basic Theoretical Research

Theoretical research on the design of transduction vibration systems is the most important basic research in power ultrasonics. China's power ultrasonics workers have done a great deal of creative work of applied value in this area.

Although filled transducers were discovered early, there has been no systematic establishment of theoretical designs for them. Because this type of transducer is highly efficient and does not require installation of a variance field, it is becoming more and more widely used in power ultrasonics. China began doing research on this type of transducer in the 1970's and provided the only design theory concerning filled transducers! We developed a wideband filled-type transducer. Research has shown that when the radiation block design is  $\lambda/4$  and when there is a rather large boring area and boring depth, not only is the transducer insensitive to fluctuations in load but it also has a rather large bandwidth.<sup>2-3</sup>

The efficiency of piezoelectric transducers under high-power conditions is an important parameter for evaluation of the qualities of transducers and thus is an important question that everyone is extremely concerned with. The Hickman Method was used to study the relationship between efficiency and load and output power as well as the frequency characteristics of efficiency.<sup>4</sup> The results show that, under high-power conditions, when the acoustic load of a piezoelectric transducer is in a state of optimum matching, its electroacoustic efficiency can reach 90 percent or even higher. When matching is rather poor, there is an obvious decline in electroacoustic efficiency. For this reason, the question of how to transfer the maximum amount of a transducer's acoustic energy to the load is an important question in power ultrasonics that requires study at the present time.

Research on "resonant frequency and efficiency of filled-type piezoelectric transducers when there is force, electric load and dissipation"<sup>5</sup> considers the internal impedance of the electrical source and the usual single-sided load conditions as well as the dissipation of metallic materials, the dielectric of the piezoelectric materials and machinery dissipation conditions to derive the resonant frequency and efficiency of the metal rod at both ends of piezoelectric components when there are different materials and different lengths, and there should be partial experimental verification. The experiments indicate that when the horizontal dimension of the transducer is less than  $\lambda/4$ , there is rather good conformity between the theoretical calculations and the measured results. As the ratio between horizontal dimensions and wavelength is increased, there also is a gradual increase in the deviation. When the horizontal dimensions are greater than  $\lambda/4$ , the effects of two-dimensional vibration should be considered. For this reason, research on design methods for horizontally-coupled amplitude-changing arms and transducers is extremely necessary. Research work in this area has begun in recent years.<sup>6-8</sup>

To solve problems in adjusting the working frequency of transducers, research has been done on the working principles of adjustable frequency piezoelectric transducers.<sup>9</sup> This type of transducer is based on changing its electric load and using piezoelectric coupling to achieve frequency adjustment. It is expected that this theory will be applied in more types of transducers.

As everyone knows, in power ultrasonics there is a load on the amplitude-changing arm under actual working conditions. The most general conditions are that there is a resistance component to the load of the amplitude-changing arm as well as an opposition component, and moreover, that they fluctuate within a certain range during the working process. For this reason, the question of how, based on load and variable qualities, to rationally design an amplitude-changing arm is a theoretical research topic of important significance in power ultrasonics at the present. Researchers have used complex variables analysis mapping theories for research on amplitude-changing arms and have successfully solved special analysis of three types of common amplitude-changing arms (circular cone, exponential and catenary types) under conditions of complex numbers and changing load impedance for further studies of power ultrasonics vibration systems in an actual working situation and have provided a new method.<sup>10</sup>

Some researchers have considered the fact that there is a load on the amplitude-changing arms and that it is not due to resonance. For this reason, existing amplitude changers will be further extended to provide a generalized theory of amplitude changers.<sup>11</sup> Based on this theory, amplitude amplification can be obtained not only at the small cross-section end of the variable cross-section arm but also in the equal cross-section arm and even at the large end of the variable cross-section arm. This has broadened ideas concerning research on transduction vibration systems.

Research also has been done on design theories for energy-focusing discs to derive solutions to ladder-shaped, conical and exponential disc energy-focusing radial vibration and torsional vibration and to plot frequency equations, displacement distributions, node positions and other calculation formulas. The theoretical calculations and measured results conform rather well.

Power synthesis is one method for obtaining high-power high-intensity ultrasonics.<sup>12</sup> A longitudinal vibration power synthesis system has been developed. It uses a certain number of transducers (3 to 4 at present) together to drive an amplitude-changing arm. This type of power synthesis transducer is already in use in ultrasonic testing of cold-drawn steel pipe. A power synthesis transducer using a vibration direction conversion amplitude-changing arm is used. An example is the R-L transducer which now is being discussed in China.

There have been studies of local covibration ultrasonic vibration systems to solve problems related to processing deep holes in brittle materials.<sup>13</sup> This type of system can work using a special pattern of local covibration. The tool length can be arbitrary and an 80 percent variation in tool length during processing is permitted. It can work excellently merely by appropriate adjustment of the frequency of the electrical generator. The significance of research work on this topic lies in the fact that it abandons the concept of half-

wavelength superimposition of a long tool rod for ultrasonic processing and that it no longer limits ultrasonic vibration systems to "total resonance" design methods, and it is easier to use.

Beginning in the 1970's, foreign countries applied the finite element method to solution of vibration problems in piezoelectric transducers, exponential amplitude-changing arms and other areas. China has undertaken applied research on this type of question in recent years, but the work has just begun and awaits further growth.<sup>14-15</sup>

In order to solve the elaborate operations involved in amplitude-changing arm design and to improve work efficiency, research has been done on the use of computers to draft design tables for ultrasonic amplitude-changing arms. Computers already have been used to draft design tables for exponential, circular cone and other types of amplitude-changing arms. The tables thus drafted are very easy to use in designing the above types of amplitude-changing arms.<sup>16-17</sup>

Furthermore, research has been done on high-efficiency ultrasonic radiators for radiating acoustic energy into the atmosphere<sup>18</sup> and on acoustic lenses used in high-frequency ultrasonic processing.<sup>19</sup> Preliminary discussions have been carried out concerning measurement of electroacoustic efficiency in power transducers under conditions of use.<sup>20</sup>

In summary, in regard to transduction vibration systems, basic work should be done in the following areas: 1) Development of high-quality transduction materials suited to use in power ultrasonics; 2) Widening frequency bands to achieve optimum matching and improve power capacity and transduction efficiency; 3) Continued research on transduction vibration systems for power synthesis and adjustable frequency power transducers; 4) Research on testing methods for transducers and energy focusers and formulation of testing standards.

Basic research in the area of applications still is very weak, especially in the areas of ultrasonic processing and therapeutics. Theory is far behind reality and many phenomena have not yet been explained. Roles and mechanisms await discussion and there is a great need for stronger research.

This article will not deal with applied research concerning the basis of each type of sentry post and the areas of emulsification, energy conservation and so on.

## II. Equipment Development and Production

More than 30 units located in 20 of China's provinces and municipalities are engaged or partly engaged in production of power ultrasonics equipment. They manufacture equipment with a frequency between 10 kHz and 1MHz and power capacities of 0.5, 3.5, 20, 35, 50, 60, 100, 200, 250, 500, 600, 1,000, 2,000, 5,000 and 10,000 watts. The equipment in use also is gradually becoming systematized and transistorization of some small power equipment has begun. The area of decreasing equipment noise has attracted the attention of many plants and some low-noise equipment now is on the market. Some equipment already has adopted automatic frequency resonance. Development and utiliza-

tion of some special equipment already has shown its might. An example is the development of special equipment for ultrasonic cleaning of steel wire, which has led to an obvious improvement in surface quality of the cleaned steel wire and greater ability to compete in international markets. Development of deep small hole processing equipment has raised deep small hole processing in glass to a new level and has received a national award. Ultrasonic rotary processors and ultrasonic microwave integrated circuit substrate processors also will be approved for going into operation. A 300 W ultrasonic generator prototype now is being used for power synthesis and ultrasonic welding equipment for engineering plastics now is being developed. Ultrasonic peritoneal dialysis machines have been put into clinical use and ultrasonic acupuncture therapy machines have been approved for operation. Good results have been obtained in animal testing of ultrasonic local heating therapy machines and there is hope for breakthroughs in the treatment of certain types of cancer.

Table 1 lists according to type several types of power ultrasonics equipment being produced in considerable amounts or which will go into wholesale production.

Based on the current situation in cleaning equipment, the following questions await consideration: 1) A further solution to instability in transducer operations and the uneven inherent stress caused by the many screws in transducers, which often leads to unwanted vibration models and rather poor stability. It appears that the tensile casing and single screw wideband form are rather stable and should be further studied and compared to select the best for use; 2) Lowering cleaning equipment noise; 3) Research on a rational layout of transducers in cleaning trough walls and other measures to strive for the greatest possible evenness in sonic fields and research on special cleaning equipment; 4) Solve problems of linking transducers and cleaning troughs, such as research on strongly adhesive, low sonic energy loss adhesives to lengthen useful life, and so on; and 5) Increase the life of cleaning troughs.

In terms of the overall situation in power ultrasonic equipment, common questions that should be considered include: 1) The fact that equipment built to identical specifications but in different factories and of different models has rather substantial differences in acoustic performance, to the extent that some identical models of equipment have obvious differences, which causes problems in actual applications; 2) Equipment performance indices now provided mainly are frequency and output electrical power under a pure resistance load, while there are no acoustic performance indices, which is a problem that must be solved; 3) Some are not matched well and have low efficiency. For this reason, we should set up testing methods and regulations for the acoustic performance of ultrasonic equipment to provide a foundation for inspection and strive to achieve optimum matching.

In the area of developmental directions for equipment, 1) Equipment systems should be decided upon as early as possible and there should be systematic production, which may benefit equipment standardization; 2) Develop wideband equipment for power synthesis; 3) Continue to develop crystal gate tubes and transistorized equipment, explore programs for power sourceless transformers

Table 1. Power Ultrasonic Equipment Now Being Produced or To Be Produced in Large Quantities in China

Equipment Name	System Model Number	Number of Products	Frequency Range (kHz)	Power Capacity (W)	Notes
Ultrasonic cleaners	CSF system	8	18-22	250, 500, 1k, 2k	
	CSF-G		800-1000	500	Not yet systematized
	H66 system	6	16.5-40	50, 250, 1k, 2k, 5k	One low-noise type
	CX system	7	20-35	50, 100, 250, 500, 1k	Crystal gate tube
	CFS system	6	-20	250, 500, 1k, 2k	
	CQ system	2	-33	50, 250	Low-noise, crystal gate tube
Others include the JCY-1 and BCQ-1 semi-automated, CQJ nuclide cleaner, Zhujiang 250-B.					
Ultrasonic cleaners	CSF-7	1	-20	100	Not yet systematized
	J93-025	1	-20	250	
	J3060	2	-20	1000	Frequency tracking
Ultrasonic tin spreader	H43	2	-20	250	
	CTX-1	1	17-19	250	
	JC-3, CPS, CSS	4	-23	-200	Not yet systematized
Ultrasonic treatment machine	C2, CSY	20	Two wave type -800, pulsed continuous	Adjustable sonic intensity levels	
Medical ultrasonic vaporizer	CW	4	1500		
Ultrasonic teeth cleaner	DJY	2	43	3.5	

Certain amounts of ultrasonic point welders (40 kHz, 0.5W), grinders, film splicers, ultrasonic membrane dialysis machines also are being produced.

and no-output transformer lines and the application of D-type amplification in ultrasonic equipment; 4) Continue to study and popularize automatic frequency resonance in equipment.

### III. Applications and Their Significance for Economic Construction

Power ultrasonics now is in wide use in industry, agriculture, national defense, medicine and public health, environmental protection and other departments. Apart from continued extension and expansion of applications with a good foundation, relatively mature technologies and obvious economic results in recent years, power ultrasonics also has achieved pleasing results in radioactive contamination, cleaning high polymers and low polymers, rapid measurements of Dacron oil content, energy conservation in emulsification of water mixed with fuels, metal forming, deep small hole processing, ultrasonic vibration cutting, polishing and grinding, synthesis of new types of copolymers, extraction of certain strong carcinogens in environmental samples, ultrasonic processing of crop seeds, medical treatments and other areas. Some examples can be used to illustrate the overall picture in the development of power ultrasonics applications and their significance for economic construction.

#### 1. Ultrasonic cleaning

Compared with other conventional cleaning methods, ultrasonic cleaning has higher efficiency and better quality. It can wash contaminants from complex parts, deep holes, blind holes and slits, and automation is easy to achieve. For this reason, ultrasonic cleaning has become an indispensable technology for many industrial departments, and it is one of the greatest primary applications of power ultrasonics.

There have been new developments in ultrasonic cleaning in recent years: 1) The spheres of application have expanded. It now is moving from the original electronics, machinery and other departments into light industry, textiles, food products, chemical industry, aviation, atomic energy, nuclear medicine and other departments; 2) There has been an increase in the number of materials cleaned. It has gradually expanded from the original semiconductor components, machine parts, optical glass and so on to cleaning wristwatches, bicycles, sewing machines, electroplated watches, medical instruments: Precision bearings, fibers, textiles and many other types of materials; 3) The target contaminants being cleaned have increased. It now has developed from the original cleaning of dust, oil contaminants and other common contaminants to cleaning lapping paste, carbon buildup, oxides, radioactive contaminants, high polymers, low polymers and other types of special contaminants; 4) The development of detergents is advancing forward and many types of synthetic detergents have been developed. The adoption of these types of detergents has provided low-cost cleaning liquids with good results that are safe to use. Other additives like solutizers, stabilizers, anti-bubbling agents, corrosion retardants and so on also can be used as supplements according to the nature of the fouling and cleaning needs to meet the various goals and needs of all types of cleaning; 5) Some have begun to do research on cleaning technologies.

## 2. Ultrasonic processing

1) Ultrasonic boring: There have been new breakthroughs in applications of ultrasonic processing of brittle materials, especially glass. The use of local resonance tool systems developed by the Applied Acoustics Research Institute can process small holes 6 mm in diameter and as much as 280 mm deep in glass. One tool arm can be used to complete processing of many holes without replacement. The total processing depth can reach 2,000 to 3,000 mm or more. The boring speed in glass (6 mm diameter) is generally 6 mm/minute.

2) Ultrasonic vibration cutting: Ultrasonic vibration cutting involves the addition of ultrasonic vibrations to machine cutting tools. It is a new precision cutting method that rather effectively solves such dangerous problems in common cutting such as great cutting resistance, high cutting temperatures, substantial parts deformation, self-excitation during cutting and so on, and it provides a new route to precision cutting and ultraprecision cutting, as shown in Table 2.

Table 2. Comparison of Common Cutting and Vibration Cutting

Cutting method	Common Cutting			Vibration Cutting		
Cutting Material	Aluminum	45" steel	Hardened steel HRC=64	Aluminum	45" steel	Hardened steel
Surface degree of finish	▽7	▽6	Cannot be cut	▽10	▽9	▽8

3) Ultrasonic vibration polishing: This adds a certain amount of ultrasonic vibration power (0.1 to 1 kW) to a polishing tool to create a high-frequency vibration along the part surface with a specific frequency (20 to 50 kHz) and amplitude (10 to 30  $\mu$ m) that, with the aid of a polish, polishes the part.

In the production of diamond wire-drawing dies, the use of ultrasonics for grinding and polishing not only works at high speed and provides a high degree of finish but also can obtain a rather long fixed diameter region in the die-hole and improve the useful life of dies. Table 3 shows that ultrasonic grinding to improve productivity of wire-drawing dies has very obvious results. This technique now is being used.

Reports from abroad indicate that ultrasonic vibration cutting not only has broad prospects for utilization in aircraft and aircraft instrument manufacture, but also has a brilliant future in turning, boring, milling, planning, punching (drilling), drilling and other techniques in regular machine manufacturing industries. Some U.S. vibration cutting equipment now is being used in industry and has been highly evaluated by the users. Japan has used ultrasonic vibration cutting not only in common equipment but also has obtained excellent applied

results in large equipment. Numerically-controlled machine tools also have adopted ultrasonic vibration systems.

Table 3. Comparison of Polishing Efficiency

Die hole specifications (mm)	Machine polishing (min./pc.)	Ultrasonic polishing (min./pc.)	Improvement in efficiency (times)
$\phi 0.08-0.20$	480	20-40	24-12
$\phi 0.21-0.40$	720	30-50	24-14
$\phi 0.41-1.20$	960	60-90	16-10.7

4) Ultrasonic metal forming: Obvious results have been obtained from using ultrasonics in cold-drawn metal pipe and all types of wire. Ultrasonic cold-drawing equipment at 2 kW and 250 W already has been developed. The characteristics of ultrasonic cold-drawing are that it can reduce the drawing force, permit multi-job continuous drawing, reduce intermediate processing and improve extension coefficients, cross-sectional compression rates, die life and lubrication. The superiority of ultrasonic cold-drawing is even more apparent in the drawing manufacture of pipes and wire made of low-plasticity materials. Obvious results also have been seen in the utilization of ultrasonics in cold-continuous rolling metal pipe. It is expected that ultrasonics will make its own contribution to reducing friction and easy removal of core rods from continuous-rolled pipe.

### 3. Ultrasonic processing

1) Applications in the pharmaceutical industry: It can prepare emulsions of excellent stability with particle diameters of about  $1\mu$  for oral use or intravenous injection. It can make new types of preparations for intravenous injection with particle sizes of about  $0.1\mu$ . Ultrasonics can be used to kill bacteria or viruses, after which appropriate methods can be used to make vaccines. In extraction of Chinese herbal medicine, ultrasonics plays a role in destroying plant organization and in accelerated dissolution and penetration of organization. For this reason, ultrasonics can be used to improve the extraction rate of the effective components of Chinese herbal medicines. An example is the extraction of alkaloids from cinchona bark. Regular methods require 5 hours or more to soak them out completely. Ultrasonics can complete the task in half an hour. There also are applications for ultrasonics in extraction of antibiotics, bactericides, sterilization, destruction of animal organization and other areas. The work has just begun, however, and awaits further intensification.

2) Applications in the areas of farm chemicals: Solids often separate out at normal temperatures in mixed and compounded liquid farm chemicals, causing work stoppages due to blocked nozzles. After 15 minutes of ultrasonic processing, the crystals are broken up and become evenly distributed. No crystals will settle out even if the equipment is set aside for 9 weeks. A 25 to 30 percent aqueous suspension of the farm chemical Sevin filtered through a 180 mu sieve still has large particles, which influences the effectiveness of the chemical. After 30 minutes of ultrasonic processing, the size becomes finer and turns it into an aqueous emulsion, with an obvious improvement in chemical effectiveness.

3) Applications in environmental protection: The (Suo) method used to extract the strong carcinogen 3.4 benzpyrene from environmental samples requires 8 to 24 hours of continuous extraction. Only 6 minutes are required if ultrasonic extraction methods is used.

4) Applications in the dyestuff industry: Originally, some 30 percent of the particles in viscose were larger than 20mu. After 15 minutes of ultrasonic dispersion, almost all of the particles become finer and less than 1mu in size. This greatly increases the effectiveness of dyes.

5) Uses in the synthesis of new types of copolymers: The effects of high-power ultrasonics have been used to synthesize partially hydrolized polyacrylamide-acrylonitrile, polyacrylic, ester-polyoxidized ethylene, partially hydrolized, polyacrylicamide-polyvinyl acetate, hydroxyethylenecellulose-polyoxidized ethylene and many other types of copolymers with many different properties that may be of use in oil and gas field development. Some of these copolymers are difficult to manufacture using conventional chemical methods. Synthesis of these copolymers opens up beautiful prospects for power ultrasonics in the synthesis of polymer materials.

#### 4. Ultrasonic therapeutics

Fairly good results have been obtained using ultrasonics in the treatment of more than 20 diseases in internal medicine, surgery, dermatology, opthamology, oto-rhino-laryngology and other fields. Moreover, there has been a new development in research on treatment methods, which is research on ultrasonic acupuncture treatment. Reports indicate that this treatment method is rather effective in the treatment of hypertension, diarrhea and bacillary dysentery. Ultrasonic permeation of medicines uses the effects of ultrasonics to permeate medicines into the body through the mucus membranes or skin. This permits realization of the benefits both of ultrasonics and of the medicine. The medicine can have direct effects on the focus, and the high concentrations of the medicines can increase the effectiveness of treatment. This method can focus and penetrate the organization rather deeply, is simple to safeguard and is easy and safe to use. A large amount of animal testing indicates that the situation is fairly good and it now is being put into clinical use. There has been an upsurge of research in this area in foreign countries and rather good progress has been made. We believe firmly that research in China concerning ultrasonic heating treatment methods will bring happiness to those suffering from neoplastic diseases. It must be noted, however, that more intensive

research concerning temperature control and measurement in the area being heated, the active ultrasonic dose for each location in the human body, the biophysical and biological effects on human organization and other topics is necessary.

During the process of writing this article, Comrade Yang Ruimin [2799 3843 3046] provided assistance often and provided his colleagues in power ultrasonics with valuable information, and we would like to thank him here.

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APPLIED SCIENCES

PLASMA ARC WELDING FOR THIN TITANIUM PLATES

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[Abstract] Techniques for flat and butt plasma arc welding are described for 3-mm-thick TAI industrial plates consisting of almost pure titanium. Welding techniques, standards, and equipment are selected experimentally, with special emphasis on the discharge of the plasma gas and the welding current, welding speed, and electric arc voltage. The parameter values recommended in the paper are compared with those for stainless steel plates, and it is concluded that the LH-300 plasma arc device can give excellent results in welding thin titanium and stainless steel plates, provided that the welding parameters and equipment quality are strictly controlled.

[Text] The relative strength and corrosion resistance of titanium materials are superior to those stainless steel. Moreover, China has abundant titanium reserves which could be of great industrial value if welding techniques applicable to titanium are found. In work undertaken jointly by our plants, we used an LH-300 plasma arc welder in experiments on flat and butt welding of 3-mm-thick TAI pure industrial titanium and 3- and 5-mm-thick type 18-8 Ti stainless steel plates. The tests showed that high-quality welded junctions can be formed using this equipment.

I. Preliminary Shaping of Weld Lines

Based on our experience, we selected a welding by the "small hole" method, in which an electrical arc is constructed (pinched) to produce a narrow hot plasma column with steep transverse and gentle longitudinal temperature gradients. The discharge of the ionized gas and the electric current have a pronounced influence on the arc temperature and voltage (cf. Table I); the high temperature and flow velocity at the center of the arc are thus primarily responsible for forming the small holes. The edges of the holes contain readily visible fine cracks associated with stress during cooling; the size of the cracks is directly proportional to the rate of welding.

Table I. Ion Discharge, Welding Current and Temperature, Arc Pressure and Gas Velocity

$Q_{ion}$ , g/sec (argon)	I, A	Temperature $K \times 10^3$	$P_{arc}$ kbar	$V_{gas}$ mm/sec
0.55	50	13	8.5	$7.1 \times 10^4$
	100	16	121.5	$1.11 \times 10^6$
	200	17.5	153	$1.34 \times 10^6$
	300	19.0	180	$1.52 \times 10^6$
1.1	50	14.5	115	$9.6 \times 10^4$
	100	17.0	164.5	$1.38 \times 10^6$
	200	19.0	252	$1.84 \times 10^6$
	300	21.0	320	$2.25 \times 10^6$

As the holes are formed, the plasma arc carries the molten metal backward (opposite to the direction of the weld), so that the metal fills up the small holes and solidifies to form a welding seam (Figure 1) as the plasma moves along the plate. Experience shows that whenever welding is aborted by pressing the emergency stop button on the device, small holes filled with unmolten metal are present. In addition, if the welding rate is too fast the pattern of small holes may be discontinuous and the surface may be pitted. The small holes are flared (of large diameter) near the top, which is directly exposed to the arc plasma; the diameter of the hole bottoms is smaller because the metal here is exposed only to the outer portion of the arc, where the pressure and temperature are lower. The dimensions of the weld seam are determined by the whole diameter, which is in turn directly influenced by the welding process parameters.

We will now analyze hole formation in titanium plates. The width  $B_{top}$  of the molten part of the seam is equal to the diameter of the top part of the holes and decreases as  $Q_{ion}$  increases, because high discharges enhance the arc pinching; however, high discharges also increase the diameter  $B_{bot}$  of the hole bottoms (i.e., the width of the molten region on the back side of the weld), cf. Figure 2. Figure 3 shows how the upper and lower diameters increase with the arc current I; this increase reflects the fact that the arc pressure and temperature increase with I. Figure 4 illustrates the increase in  $B_{bot}$  and the decrease in  $B_{top}$  as the arc length L increases.

## II. Selecting Appropriate Arc Welding Standards and Equipment

In addition to the low specific mass (4.505) of pure TAI industrial titanium, the material is corrosion-resistant and has a specific strength 2.5 times greater than for stainless steel. Because of its high melting point (1680°C) and low heat conductivity [0.04 cal/(mm·sec·°C)] high temperatures persist for long times in the weldpool, and rapid cooling is required to keep the hot region from becoming too large and to avoid excessive crystal growth associated with overheating.

Figure 1. Formation of small holes and weld. 1) hole formation; 2) weld seam during formation of hole 2; 3) formation of weld seam and hole 3.

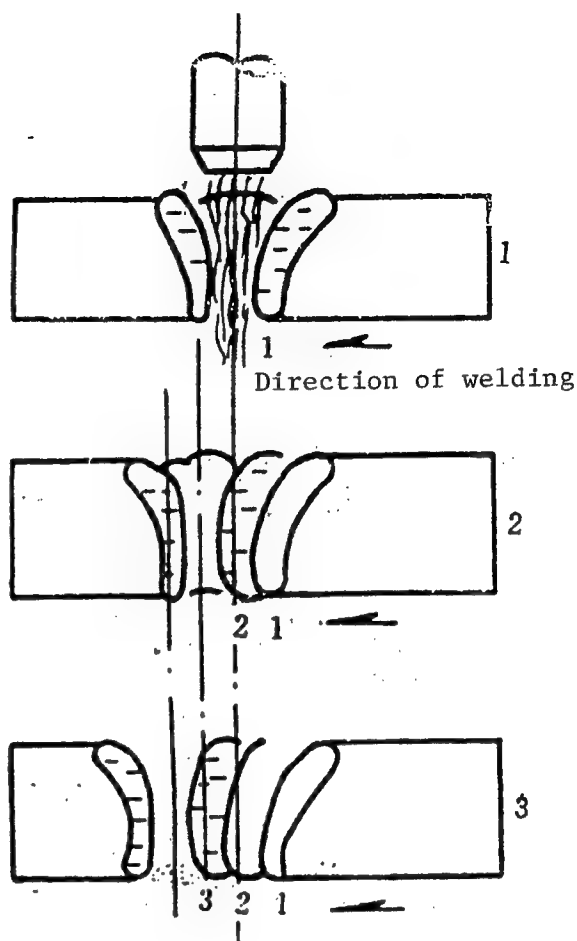


Figure 2. Hole diameters ( $B_{top}$ ,  $B_{bot}$ ) as a function of the discharge of ionized gas for  $I = 190$  A;  $v_{weld} = 292$  mm/min;  $L_g = 9$  mm;  $L_{in} = 3$  mm. The plate was 5 mm thick.

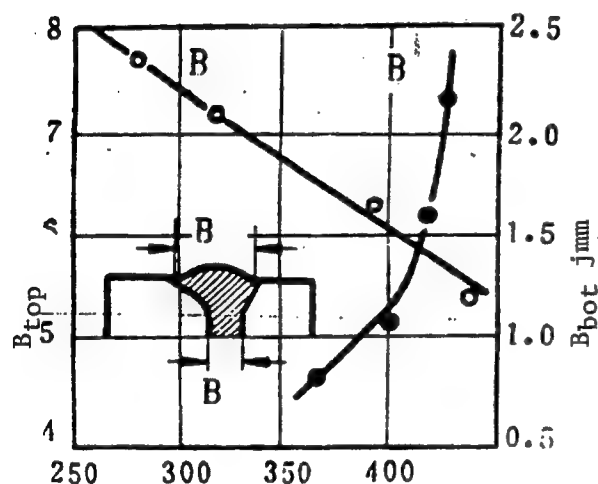


Figure 3. Hole diameters  $B_{top}$ ,  $B_{bot}$  as functions of the electric current during welding;  $V_{weld} = 292$  mm/min,  $L_g = 9$  mm,  $L_n = 3$  mm.

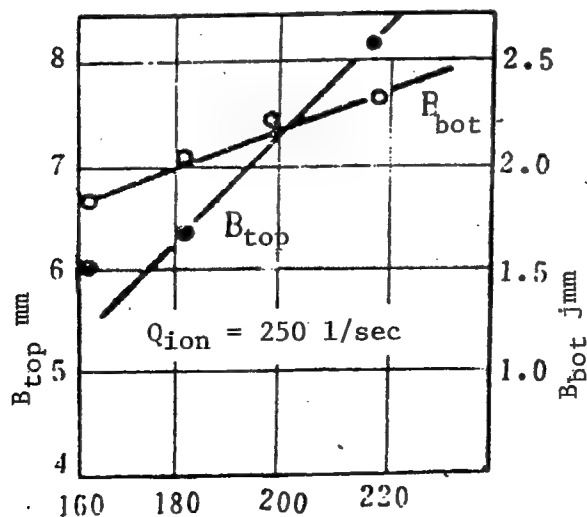
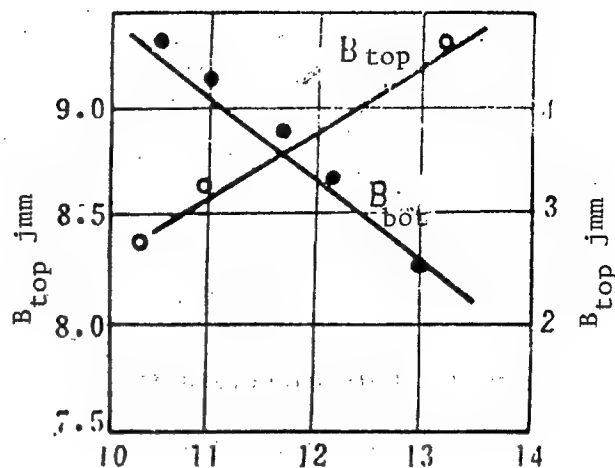


Figure 4. Hole diameters  $B_{top}$ ,  $B_{bot}$  as functions of  $L_g$  of the arc;  $I = 190$  A,  $v_{weld} = 292$  mm,  $L_{in} = 3$  mm.



Titanium is chemically reactive (almost as reactive as sodium and magnesium) and absorbs hydrogen, oxygen, and nitrogen in the hot solid or liquid states (300 - 600°C). These dissolved gases result in the formation of TiO ( $\gamma$  phase), TiN ( $\delta$  phase), and TiH<sub>2</sub> ( $\gamma$  phase), which increase the strength of the metal but greatly decrease its plasticity. Titanium exists in the densely-packed hexagonal  $\alpha$  phase at room temperature but undergoes an allotropic transformation to the bcc  $\beta$  phase upon heating to 885°C. If kept for long at high temperatures, crystal growth will thus make the material brittle (less plastic). The supersaturated hydrogen present in the  $\alpha$  phase after rapid quenching distorts the atomic order in the crystal and gives rise to an unstable  $\alpha'$  martensite phase consisting of a needle-like structure.

The chemical composition of TAI (in percent) is: Fe 0.019, Si 0.03, C 0.015, N 0.04, H 0.0039, O 0.118, with the remainder being titanium. This composition requires that special welding techniques, equipment, and standards be developed for assuring reproducible weld structures and properties.

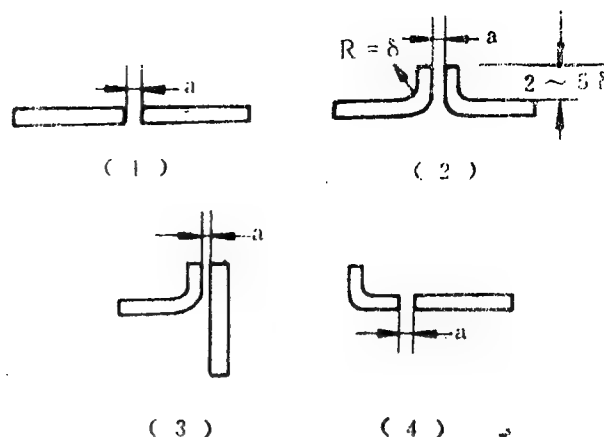
#### 1. Cleaning prior to welding

The preparation (cleaning) of the surface prior to welding greatly affects the weld quality, because the surface material melts spontaneously (is self-fusing) in the protective argon arc, which prevents ordinary chemical reactions (oxidation, reduction) from occurring. It is thus necessary to first clean the surface with acetone or ethanol and dry it before welding. Alternatively, the material can be chemically cleaned in 40 percent HNO<sub>3</sub> + 3 percent NaF aqueous solution for 15 - 20 minutes at room temperature, after which the surface is wiped clean and dried before welding.

#### 2. Weld formation

The different types of welds shown in Figure 5 were formed in TAI plates 1 - 3 mm thick (flat butt welds, angle welds, and modified butt or curved-edge welds).

Figure 5. Welding geometries.  
1, 4)  $\frac{a}{\delta} = 0.2\delta$ ; 2, 3)  
 $\frac{a}{\delta} = 0.6\delta$



### 3. Process Control

Adequate control is critical in titanium welding, as otherwise mottling will result. Silver-white metal (the intrinsic color) has the best properties, but a silver white  $\rightarrow$  yellow  $\rightarrow$  blue transition occurs if the process is poorly controlled; both the oxidation and the other properties of yellow and blue metal are distinctly inferior (Table II).

Table II. Metal Color and Cold-Bending Angle after Welding

Color	Cold-bending angle	Color	Cold-bending angle
Silver white	115°	Light blue	66°
Light yellow	88°	Dark blue	21°
Dark yellow	71°	Gray-blue	0°

Thus, in addition to the protective gas envelope at the orifice of the arc welding tool, we used a moving protective cover (shield) while working on the front side of the welding seam. The shield (a sliding copper plate) was 200 mm long and 60 mm wide; these measurements were chosen on the basis of the heat distribution in the titanium plate (cf. Figure 6). The shield was placed tightly on the seam behind the welding front and followed the welding gun; the interior of the water-cooled shield contained a protective argon atmosphere. Desirable silver-white weld seams were produced by this method in all cases. We also used type V copper pads to shield the back side of the weld from the hot plasma; 10 x 1 mm copper tubes were inserted through small perforations in the pads into the argon gas (Figure 7). The results here were also excellent--silver-white seams were produced in all cases. The plates were clamped by rigid earth-filled frames to prevent buckling distortions and keep the spatial intervals constant.

#### 4. Selection of Process Conditions

We first analyzed the parameters of the arc welding process, including  $Q_{ion}$ ,  $I$ , and  $V_{weld}$ , together with the geometric parameters shown in Figure 8.

(1) The discharge  $Q_{ion}$  of the ionized gas is a crucial factor influencing the stability of the electric arc and the depth to which the metal is melted, as well as the form of the weld seam. As  $Q_{ion}$  increases (Figure 9), the arc temperature and pressure increase significantly, and the plasma column is pinched. As a result, the weld becomes deeper and narrower (the region of molten metal on the back side of the weld becomes slightly broader). If  $Q_{ion}$  is excessively large ( $Q_{ion} \gg 250$  liter/sec), nicking and cutting of the metal will occur; further increases will cause turbulent convection and secondary arcing which degrades the surface of the welded seam. If  $Q_{ion}$  is too low ( $< 250$  liters/sec) the plasma column will not be narrow enough, and the weld will be too shallow and broad (incomplete welding).

Figure 6. Sketch of sliding water-cooled copper shield. 1) plasma arc gun; 2) copper shield; 3) spring clamp.

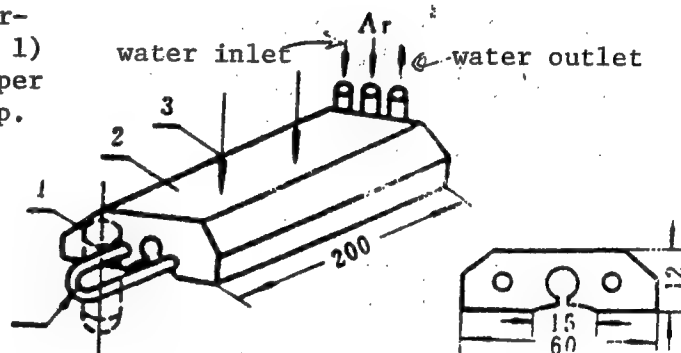
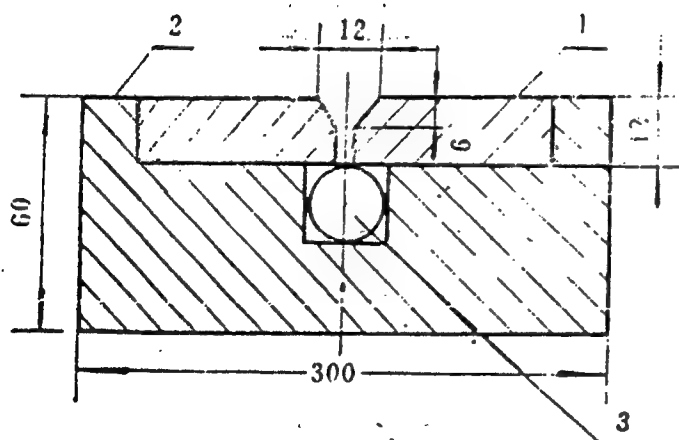


Figure 7. Structure of copper plate (pad) used to protect the back side of the weld. 1) copper lining; 3) perforated red copper tube for supplying argon gas.



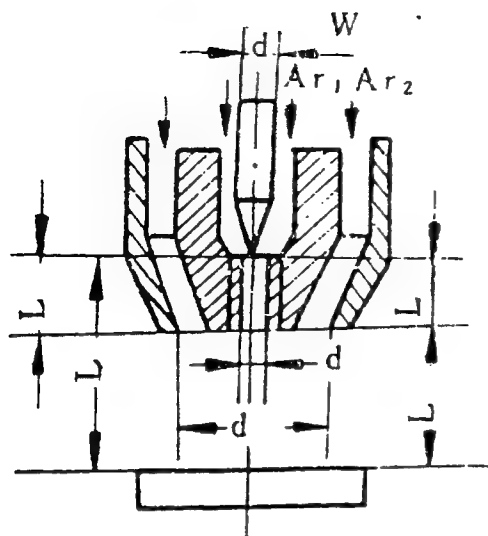


Figure 8. Diagram showing geometry of plasma arc nozzle.  $L_{in}$ , width of tungsten plate;  $L_t$ , length of clamped tapered region;  $L_g$ , arc length;  $L_n$ , distance between nozzle and welded plate;  $d$ , diameter of tungsten plate;  $d_t$ , diameter of compressed hole;  $Ar_1$ , flow of ionized gas;  $Ar_2$ , flow of protective gas;  $d_p$ , diameter of protective orifice;  $L_g = L_n + L_{in}$ .

(2) As the welding current  $I$  increases, the weld becomes deeper and wider (Figure 10), but excessive currents result in double arcing, which damages the nozzle of the welding gun. If  $I$  is too small, the weld will be incomplete (too shallow and narrow).

(3) The welding productivity of course increases with the welding rate  $V_{weld}$ . However, excessive rates will result in narrower, shallow seams and a coarsely rippled surface; gas holes and other types of discontinuities in the weld seam may also be present (Figure 11). If  $V_{weld}$  is too low, excessive heating will scorch and burn through the surface.

Figure 9. Weld height and breadth and weld voltage as functions of the discharge of ionized gas.  $I = 190$  A,  $v_{weld} = 292$  mm/min,  $L_g = 9$  mm,  $L_{in} = 3$  mm.

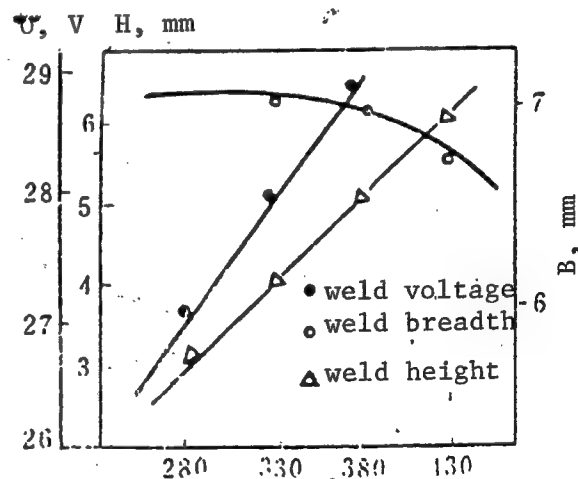
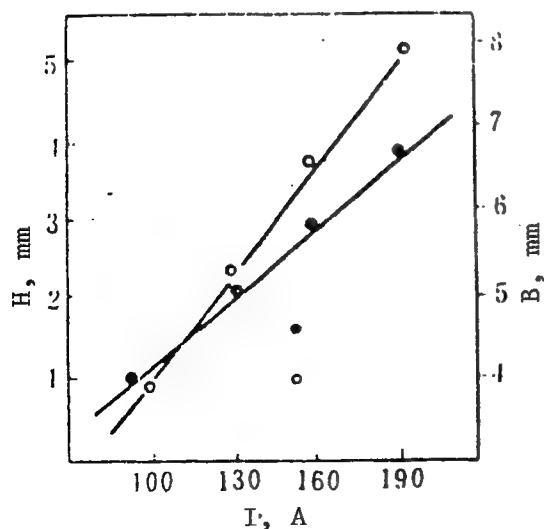


Figure 10. Weld height and breadth vs welding current;  $Q_{ion} = 240$  liter/h,  $U = 29$  V,  $v_{weld} = 292$  mm/min,  $L_g = 9$  mm,  $L_{in} = 3$  mm.

(4) The arc voltage  $U$  is proportional to the length  $L_{in}$  of the central part of the arc (Figure 12). For  $L_{in} = \text{const}$ , one can alter  $U$  by varying the distance from the gun nozzle to the plate. Although  $U$  increases with  $L_{in}$ , the temperature, arc pressure, and the cross section of the plasma column all increase slightly, so that the weld becomes broader while its depth remains essentially unchanged. If the arc is too long it will be unstable, so that the argon gas will not protect the metal sufficiently and weld quality will be degraded. Multiple arcing may occur if the arc is too short. In practice, one generally takes  $L_g = 6-8$  mm,  $U = 20-30$  V,  $L_{in} = 2-4$  mm.

(5) We recommend the following parameter ranges for butt-welding 3-mm-thick TAI plates:  $I = 160-170$  A,  $U = 26-27$  V,  $v_{\text{weld}} = 30.7$  m/h, nozzle diameter 3 mm, tungsten electrode diameter 4 mm,  $L_{in} = 3$  mm,  $Q_{ion} = 220$  liter/h, protective gas discharge 1300 liter/h; the flowrate of protective gas in the moving copper shield should be 1500-3000 liter/h, and the flowrate just behind the weld should be 1500 liter/h.

Figure 11. Influence of welding rate on weld height and breadth.  
 $I = 180$  A,  $U = 23-25$  V,  
 $Q_{ion} = 240$  liter/h,  $L_g = 9$  mm,  $L_{in} = 3$  mm.

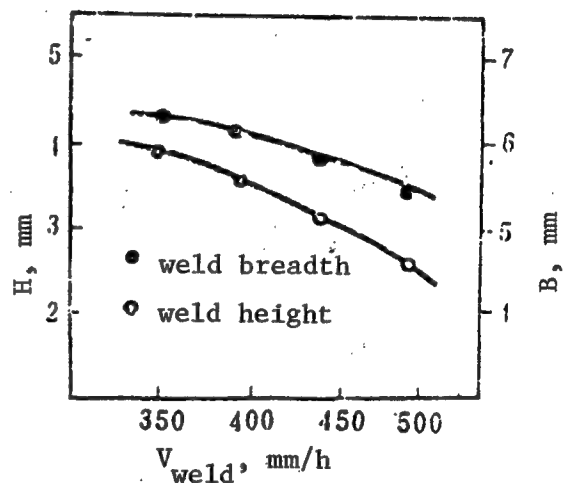
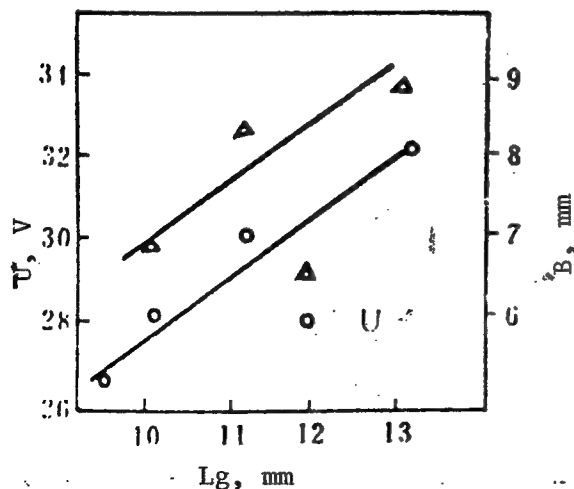


Figure 12. Influence of arc length of welding voltage and breadth.  
 $I = 190$  A,  $Q_{ion} = 250$  liter/h,  
 $v_{\text{weld}} = 292$  mm/min,  $L_{in} = 3$  mm.



(6) The following problems must be addressed during welding:

a) the preheating time must be carefully regulated. If this time is too long, the holes formed by the arc will be large and the weld seam will be discontinuous (cut up). If the preheating time is too short, no holes will form and complete welding cannot occur. The preheating time must thus be appropriately increased as the plate thickness increases. The preheating time for 3-mm-thick stainless steel or titanium plates should be 0.5-1 sec (grade 1-2); for 5-mm-thick plates (grades 3-5), the preheating time should be 1-3 sec.

b) The weld edges may be uneven (either unilaterally or on both sides); this is caused by excessive welding rates or inadequate currents. Moreover, the starting material melts spontaneously, which increases the likelihood of uneven edges and incomplete hole filling; it is therefore necessary to fill up the gaps in the welding wire or to regulate the welding rate and current. The welding nozzle must be aligned at the center of the gap; improper alignment (by more than 5 percent of the plate thickness) may result in irregular edges.

3. Multiple arcing must be avoided. One must remember that in this case the metal is not well protected, so that the constraints on the equipment, welding parameters, and tungsten plate alignment are more stringent than for ordinary argon arc welding.

### III. Welding Results and Analysis

Table III summarizes the experimental results for 3-mm-thick TAI plates.

Table III. Mechanical Properties

Material	$\sigma_b$ kg/mm <sup>2</sup>	$\delta$ %	$\psi$ %	Cold-bending angle $\alpha$ (front)
TAI (starting material)	52.70	30.5	--	>137-141°
Weld material	51.30	20	53	150°
(surface untreated)	51.10	20	53	135°
	50.70	21	54	--
Average	51.30	20.3	53.3	142.5°

1. X-ray analysis revealed no welding defects; i.e., the welds were of class I.

2. We tested the welded plate for mechanical strength; fracture did not occur at the weld but at a distance of 20 mm from it in the original TAI material. The cold-bending angle  $\alpha$  of the front surface of the welded seam was equal to 142.5° which was greater than for the starting material (Table III). The metal phase composition at the seam was  $\alpha$  plus a small amount of  $\alpha'$  phase; a coarse  $\alpha + \alpha'$  phase structure was present slightly farther away from the seam.

We also butt-welded 3- and 5-mm-thick stainless steel plates (of composition 1Cr18Ni9Ti); surface cleaning was still necessary in this case, but the region immediately behind the advancing weld did not require protection (no copper shield was needed). Table IV shows the relevant parameters. The welds for stainless steel had a corrugated appearance and were slightly inferior to the welds obtained in the titanium plates; nevertheless, the admissible range of welding parameters was wider, cf. Table V. The welds in this case consisted of austenite plus 10-15 percent ferrite (a small amount of impurity was also present). The coarse-grained austenite present in a region 2-3 mm thick was formed because of the local heating during welding.

We may summarize the results as follows. The LH-300 plasma arc welder gives good results for thin stainless steel or titanium plates. However, high-quality equipment and good plate-packing and protection systems are needed, and the process parameters must be strictly controlled. In view of the great industrial potential of titanium, our experimental results (while still incomplete) may help to improve industrial weld quality and productivity.

Table IV. Parameters for 1Cr18Ni9Ti Steel Welds

$\delta$ , mm	Clearance, mm	I, A	U, V	$v_{\text{weld}}$	$Q_{\text{ion}}$ , l/h		$Q_p$ , l/h
					I	II	
3	0.5	180-185	30-31	512	235	100	1600
5	0.5-1	185-190	29-30	260-290	250	150-180	1600

Note:  $L_{\text{in}} = 3$  mm,  $d_w = 4$  mm,  $d_{\text{nozzle}} = 3$  mm.

Table V. Properties of Weld Seams in 1Cr18Ni9Ti Steel

	C	Cr	Ni	$\sigma_b'$ , kg/mm <sup>2</sup>	Cold-bending angle $\alpha$
Initial material	0.12	17.15	9.1	55	180°
Welded material	.094	17.15	9.0	57.2	180°
				58.2	180°
				57.8	180°
Average				57.7	180°

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CSO: 4008/359

APPLIED SCIENCES

FAST PRECONCENTRATIONS OF URANIUM FROM SEAWATER, ITS DETERMINATION

Beijing HAIYANG KEXUE [JOURNAL OF MARINE SCIENCE] in Chinese No 1, 9  
Jan 85 pp. 29-31

[Article by Zhou Zhonghuai [0719 0112 2037] and Xu Lijun [1776 7787  
0689] of the Chinese Academy of Sciences Institute of Oceanology]

[Text] We discovered that the use of aluminum hydroxide as a coprecipitant and clamshell powder as a carrier can preconcentrate uranium from seawater rather well. This article systematically studies the effects of carrier coprecipitant conditions on preconcentration and uses this method to determine the concentration of uranium in seawater along the shore off Huiquanwan in Qingdao.

I. Experimental Methods

1. Reagents and instruments

1) Aluminum sulfate (refined industrial product), 2) clamshell powder, 3) sodium hydroxide (A.R.), 4) ammonium carbonate (A.R.), 5) nitric acid (A.R.), 6) disodium ethylenediaminetetracetic acid (A.R.), 7) tributyl phosphate (L.R.), 8) kerosens (processed with activated carbon), 9) ammonium nitrate (A.R.), 10) uranium reagent III (A.R.), 11) electric agitator, 12) model 72 spectrophotometer.

See HAIYANG KEXUE No 4, 1984 for a report on processing the clamshell powder.

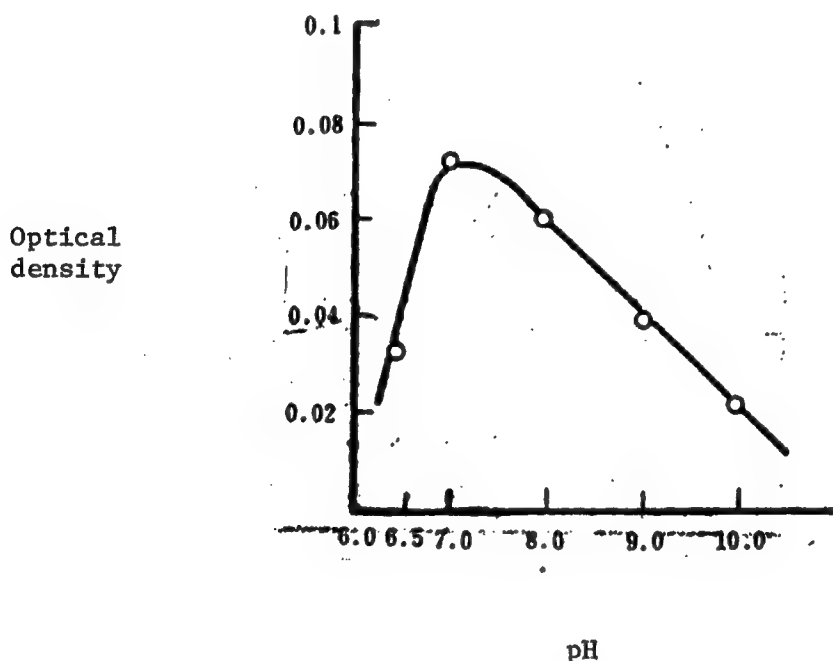
II. Experimental Results and Discussion

1. Experiment on coprecipitation conditions.

We did experiments on the effects of solution pH, aluminum sulfate concentration, clamshell powder content, solution temperature and re-agitation time after coprecipitation on preconcentration of uranium. The results are described below.

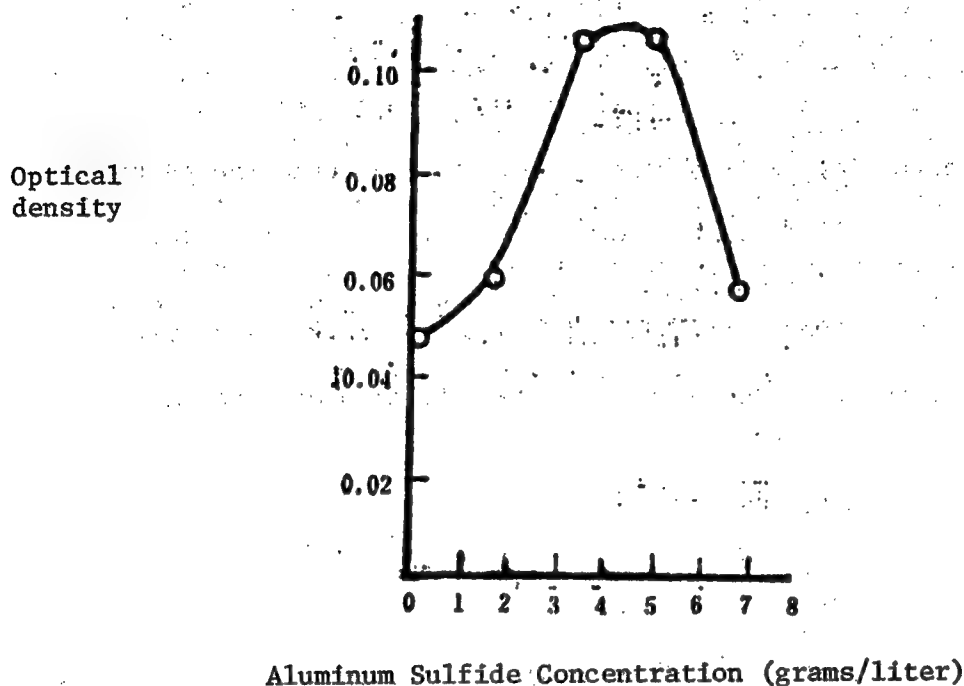
1) Effects of solution pH; pH has rather great effects on the coprecipitation of uranium, beginning to rise dramatically at 6.5 and reaching a maximum value at 7.0. The amount of uranium coprecipitation falls rather quickly after 7.0, as shown in Figure 1. This makes control of pH is rather important during coprecipitation. Because the aluminum sulfate solution has a pH of 1 to 2, the pH is changed following the addition of clamshell powder because some of the calcium carbonate is dissolved, which plays a certain role in regulation of pH. After agitation for 5 minutes, dissolution of the calcium carbonate plays only a minor role, and readjusts the pH to 7.0 and the uranium is coprecipitated by the carrier. After coprecipitation, it is best in principle to filter it immediately. The effects of pH on coprecipitation are due mainly to changes in the surface electrical qualities of the preconcentrate. This is an important factor in the preconcentration of uranium from seawater.

Figure 1. Effects of Solution pH on Coprecipitation of Uranium



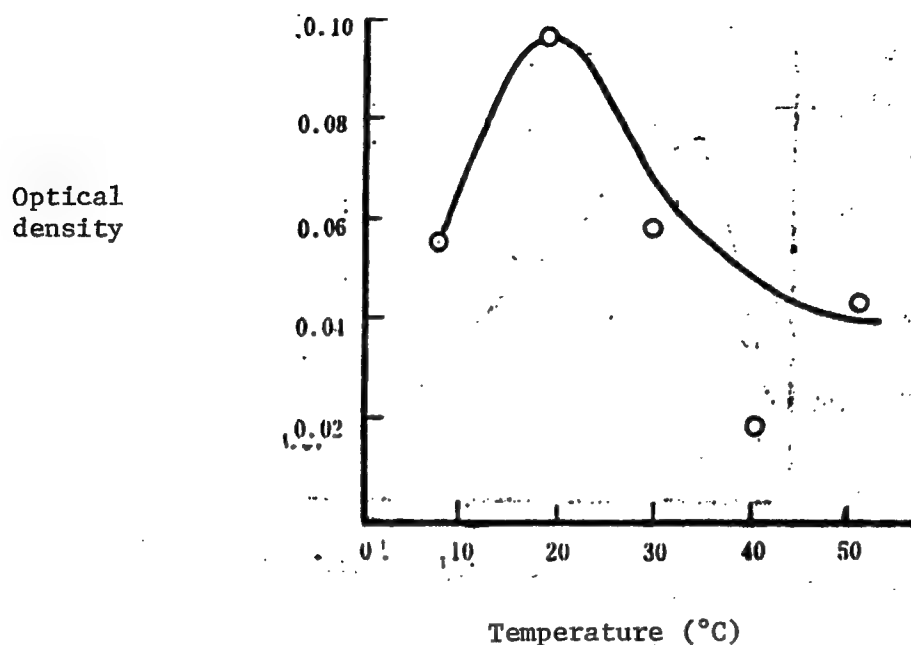
2) Effects of aluminum sulfate concentration: the optimum aluminum sulfate concentration for coprecipitation of uranium is 3.34 to 5.0 grams/liter, and it begins to drop rapidly after 5.0, as shown in Figure 2. The reason may be that increased aluminum sulfate concentrations may reduce the effective comparative surface. We used a concentration of 3.34 grams/liter during preconcentration.

Figure 2. Effects of Aluminum Sulfide Concentrations on Uranium Coprecipitation



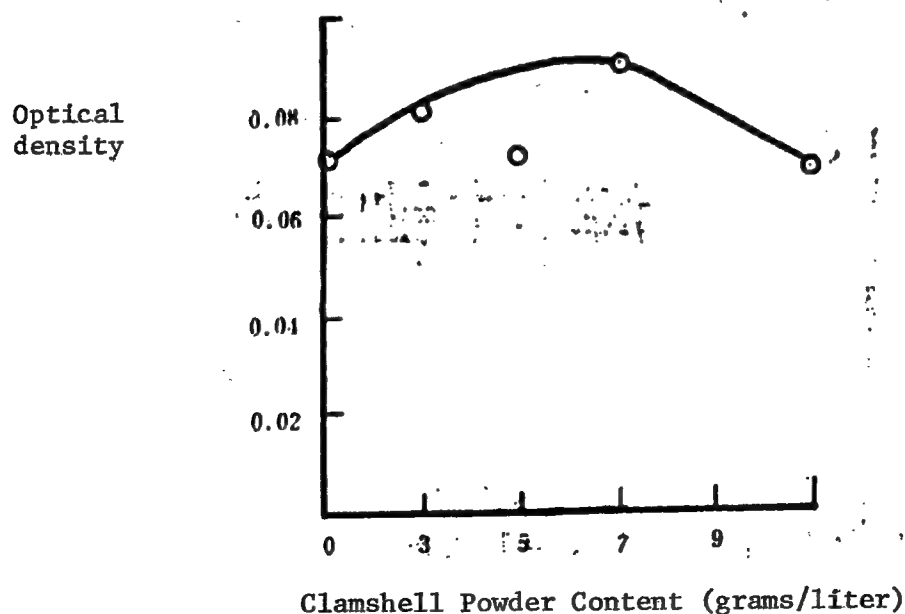
3) Effects of solution temperature: solution temperature has rather great effects on the preconcentration of uranium during coprecipitation. The results of coprecipitation were best when the solution temperature was 19°C, and the effects began to fall after 19°C, as shown in Figure 3. This is due primarily to the changes that occur in aluminum hydroxide structure under different temperatures. Generally speaking, an increase in solution temperature causes a reduction in effective comparative surface and the pore diameters become smaller, which effects the amount of preconcentration of uranium.

Figure 3. Effects of Solution Temperature on Coprecipitation of Uranium



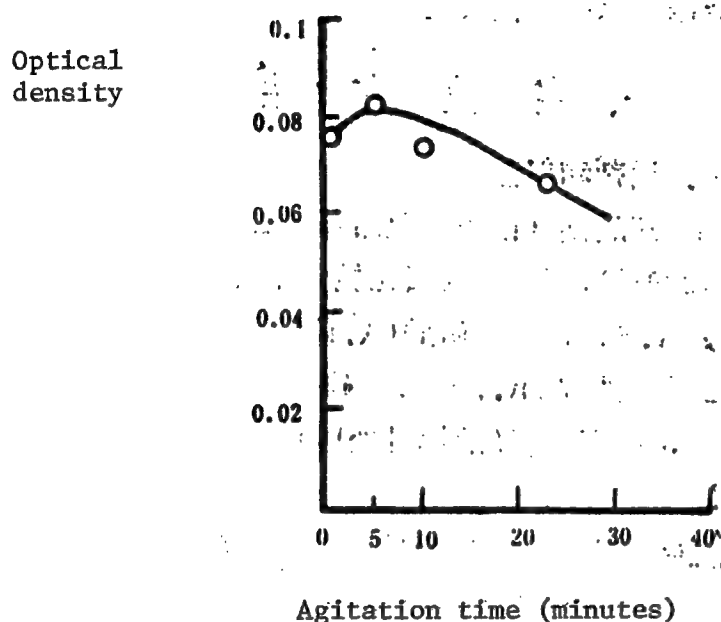
4) Effects of the amount of clamshell powder: the amount of clamshell powder added also has certain effects. When the amount is small, carrier coprecipitation is incomplete, while larger amounts may have opposite effects, causing reduced results of carrier coprecipitation, as shown in Figure 4. The experiments showed that it is best to add 7 grams per liter of seawater.

Figure 4. Effects of Clamshell Powder Content on Uranium Coprecipitation



5) Effects of agitation time after coprecipitation: the agitation time after coprecipitation also affects the preconcentration of uranium. Re-agitation for 5 minutes after coprecipitation improves the results of carrier coprecipitation for preconcentration of uranium somewhat, as shown in Figure 5.

Figure 5. Effects of Re-agitation After Coprecipitation on Preconcentration of Uranium



## 2. Experiments on recovery rates

The experiments were carried out in the following manner: 1) We first used the cocarrier precipitation method to determine the concentration of uranium in the seawater. 2) Next, we added 5.0 ug of standard uranium to a beaker containing one liter of seawater and used the operations method for determination of uranium in seawater to derive the uranium concentration after adding the standard uranium. This permitted us to derive a uranium recovery rate of 86 to 100 percent, as shown in Table 1. We can learn from the recovery rates shown in Table 1 that the carrier coprecipitation efficiency of this method was 86 to 100 percent.

Table 1. Experiments on Recovery Rates (units: ug/liter)

Amount of Uranium in one liter of seawater	Uranium added	Measured Uranium	Recovered Uranium	Recovery rate (%)
2.65	5.0	6.95	4.30	86
2.65	5.0	7.63	4.98	99.6

Note: Uranium concentrations in seawater and measured uranium concentrations are average values.

### 3. Effects of interfering ions

Experiments on the effects of interfering ions were based on a carrier coprecipitation efficiency of 100 percent. Various types of interfering ions were added directly to the seawater to determine their effects on carrier coprecipitation. The results of the experiments are shown in Table 2. We can learn from Table 2 that, apart from a positive relative deviation for  $\text{Fe}^{3+}$  and the excessively high results, the results of the other interfering ions were rather low.

Table 2. Effects of Interfering Ions on Measurement of Uranium Using the Carrier Coprecipitation Method

Interfering ions added <sup>(1)</sup>	Measured <sup>(4)</sup> Uranium (ug/liter)	Recovery rate (%)	Relative deviation (%)
10 ug uranium	10.25	102.5	+2.5
10 mg $\text{Fe}^{3+}$	11.10	111.0	+11.0
10 mg $\text{Al}^{3+}$ (2)	9.75	97.5	-2.5
10 mg $\text{Al}^{3+}$ (3)	9.10	91.0	-9.0
20 mg $\text{Mn}^{2+}$	6.70	67.0	-33.0
20 mg $\text{Mg}^{2+}$	5.80	58.0	-42.0
1 ug $\text{Th}^{4+}$	5.10	51.0	-49.0
20 mg $\text{Ca}^{2+}$	6.90	69.0	-31.0
50 mg $\text{SO}_4^{2-}$	5.00	50.0	-50.0

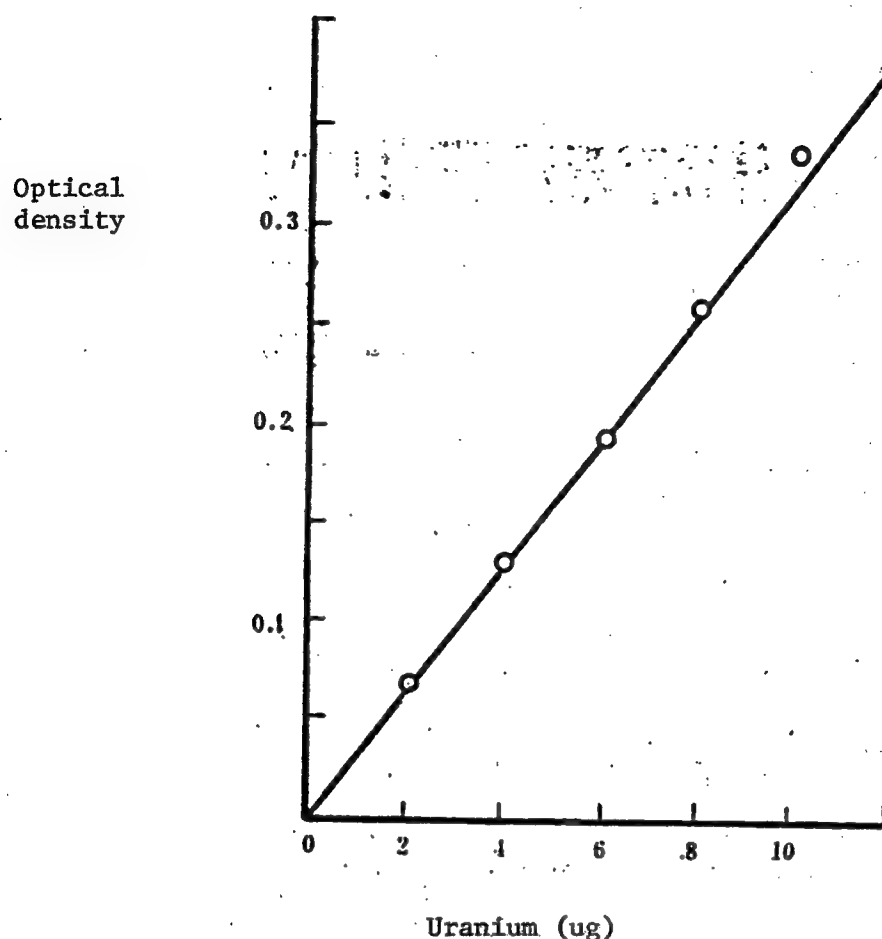
#### Notes:

1. All added to one liter of seawater
2. A solution matched with  $\text{Al}(\text{NO}_3)_3$ (A.R.)
3. A solution matched with  $\text{Al}(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ (A.R.)
4. Baseline value of the uranium in the seawater already subtracted.

#### 4. Plotting the work line

We added 2.0, 4.0, 6.0, 8.0 and 10.0 ug of standard uranium to a separation funnel and then added 10 ml of 60 percent ammonium nitrate solution (containing disodium ethylenediaminetetracetic acid) and enough distilled water to raise the total volume of the water facies to 15 ml. After the pH was readjusted to 2.0 to 2.5, we added 15 ml of a 1:4 tributyl phosphate--Kerosene solution. After 3 to 5 minutes of extraction and settling into layers, the water facies were poured out and 15 ml of 0.1 percent uranium reagent III solution was added. After counterextraction for 3 to 5 minutes, the uranium reagent III solution cleared and we carried out spectrophotometric determinations. A chart of uranium concentrations based on optical density was drawn and we plotted the work line of the known uranium content in preparation for use as water samples. The work line is shown in Figure 6.

Figure 6. Work Line of Optical Density and Uranium Content



##### 5. Carrier coprecipitation preconcentration operations and uranium determination

We added 3.34 grams of aluminum sulfate to one liter of water in a 2,000 ml beaker. After agitation and dissolution, we then added 7 grams of clamshell powder. After 5 minutes of combined precipitation and agitation, sodium hydroxide solution was used to readjust the pH to 7.0. After carrier coprecipitation, we continued agitating for 5 minutes and then filtered it immediately. The precipitate was transferred to a 100 ml tall beaker and 40 ml of 1 mole ammonium carbonate solution was used for 3 desorptions. The desorbed liquid was divided into two parts and neutralized using nitric acid. Moreover, it was heated until nearly dry, after which it was transferred to a separation funnel. The subsequent operational steps are described in the part on plotting the work line.

We used this method to determine that the average uranium concentration in the seawater along the eastern shore off Huiquanwan in Qingdao was 2.75 ug/liter.

APPLIED SCIENCES

JAPANESE REPORT ON CHINA'S F-8 FIGHTER

Beijing HANGKONG ZHISHI [AEROSPACE KNOWLEDGE MAGAZINE] in Chinese No 7,  
Jul 85 pp 22-23

[Translated by Yu Yuebo [0060 6460 3134]]

[Text] Mach 2 Class Fighter Aircraft

A new Chinese-built fighter aircraft has been unveiled. This aircraft, which is named the F-8, has a delta wing and a horizontal tail; it probably has two engines, and its maximum speed is estimated to be greater than Mach 2. According to the article "1983-1984 Military Balance", approximately thirty F-8 aircraft are currently in service in the Chinese Air Force.

Sometime ago it was rumored in Western circles that China was developing its own Mach 2-class fighter. According to the 1983-1984 edition of "Jane's Aircraft", China began developing the F-8 in the mid-70s. In 1976, China obtained a small number of MiG-23s from Egypt, and thus acquired some of the MiG-23 technology; the F-8 was thought to be a delta-wing aircraft with no tail. In September 1980, a team of representatives from the U.S. Department of Defense and the U.S. aerospace industry were invited to tour the factory making the new fighter aircraft and reported that the aircraft was equipped with a Chinese-built Tumansky R-11 turbojet, and that it was a Mach 2-class aircraft ready for production. But according to a Defense Intelligence Agency report in July 1981, the F-8 was not in production because China was not able to build a high-thrust engine used on modern fighters. The thrust produced by the Tumansky R-11 engine was inadequate for the F-8, and the Tumansky R-29 engine used on the MiG-23 was beyond China's manufacturing capability. The Rolls Royce Spey 202 engine for which China obtained a license from Britain to manufacture was not yet in production. Consequently, Western experts at that time estimated that the new Chinese fighter would not be produced for at least several years.

The F-8 which China actually unveiled turned out to be different from the above observations. From its air inlet design and the centered, single delta-wing configuration, one can see that its design is primarily based on the Chinese-built MiG-21. Compared with the MiG-21, the F-8 has a longer fuselage forward of the wing in order to increase fuel capacity; also, the air inlets are enlarged in order to accommodate a higher rate of air intake. The cockpit

of the F-8 is different from the F-7 cockpit; the latter has a frameless cover which opens forward, whereas the former has a framed cover which opens toward the back and the side. The dimensions of the wing and tail of the F-8 are also larger, but the centered single wing and the lower horizontal tail designs are identical to those of the F-7. The F-8 has a wider rear fuselage which reflects the parallel dual engine configuration. On each side of the fuselage is a ventral fin extending outward. In terms of the overall layout of the f-8, it closely resembles the "Fire Rod" (Ye-150-151?) experimental aircraft designed by the Mikoyan Design Institute and flown only once by the Soviets during the Tushino Air Show in 1961. The F-8 engines are probably the Chinese-built Tumansky R-11 (single engine thrust of 11,340 kg from both engines. The total weight of the aircraft is estimated to be around 13,500 kg, and the thrust-to-weight ratio is around 0.84. Its performance is superior to the U.S. F-4 "Phantom" and the F-5E "Tiger" II fighter aircraft.

As to the weapons system of the F-8, it is still unclear. The air inlet is equipped with a shock wave cone which appears to contain a radar but judging from the small size of the shock wave cone, it is probably not a high-performance radar.

#### China's Long Struggle To Develop a Supersonic Fighter

In the mid-1970s, under licence to produce the Soviet MiG-15, China began its jet fighter development. Subsequently, as the Soviet Union advanced from the second-generation subsonic fighter MiG-17 to the first-generation supersonic fighter MiG-19, China also obtained the licence to produce these aircraft. But by the 1960s, the Sino-Soviet conflict came into the open; only a very few MiG-21s were given to China, and the transfer of aeronautical technology from the Soviet Union also stopped. It was then China began to manufacture its own MiG-21 and the Tumansky R-11 engine. In December 1964, the Chinese-built MiG-21F (F-7) No 1 made its first flight; by the following year, it went into military service.

But right at this time, the Cultural Revolution in China started, and the development of all new technologies came to a halt. Production of the just-developed MiG-21 also stopped after producing only 60-80 aircraft. In its place, production of the Chinese-built MiG-19 (F-6) was greatly increased; ultimately, several thousand F-6s were produced.

When the Cultural Revolution was terminated in 1976, China began its modernization programs, and the production of the F-7 was resumed. The air-to-ground attack aircraft A-5 was designed based on the MiG-19. In the overall layout, the air inlets were moved to the two sides, and a bomb bay was installed inside the fuselage (actually it occupied the space of the fuel tank). Development of this aircraft began in the early 1960s and it went into military service in the early 1970s.

Today, the F-6 is still the primary fighter aircraft of the Chinese Air Force. This aircraft has several different models: the daytime interceptor model, the fighter-reconnaissance model, and the limited all-weather model. There are a total of more than 3,000 F-6s which are assigned to more than 40 flight

groups. For air-to-ground combat missions, the Air Force use approximately 500 old MiG-15s (F-4) and A-5s.

The Chinese-built MiG-19 (F-6) is exported to certain countries which include Pakistan (140 aircraft), Egypt (50 aircraft), and other countries such as Tanzania, Albania, Bengal, Cambodia, and Zimbabwe. In addition, they are also exported to Iran through North Korea, and to Iraq through Egypt and Jordan. The F-7 has also been exported, including 160 to Egypt, some of which have been transferred to Iraq.

Albania and Tanzania are both equipped with Chinese-built MiG-21s. In 1983, the Zimbabwe Air Force equipped an entire flight group with Chinese-built MiG-21s. Furthermore, since February 1983, China began shipping 42 A-5s to the Pakistan Air Force for its 16th Flight Group.

#### Closing a 20-Year Gap

When the F-6 (MiG-19) was first flown in 1953, its maximum Mach number was 1.45. In terms of Western standards, it belongs to the same generation as the North American F-100 "Super Sabre" aircraft. Compared to the U.S. F-15, F-16, and the Soviet MiG-23, MiG-25, and newer fighter aircraft, there is generally a 20-year gap. Even the F-7 is only comparable to the earliest model of the MiG-21--MiG-21F, which was the first generation Mach 2 class fighter aircraft. Although there are as many as 3,000 F-6s, the fact that it is still used as the primary fighter aircraft illustrates the severe damage the Cultural Revolution inflicted on China's technological development.

The development of the F-8 shows China's attempt to make up the loss suffered during the Cultural Revolution. Although the performance and equipment of this airplane are not clearly known, the F-8 is not considered to be technologically as sophisticated as the F-15, F-16, or the MiG-23. It has been reported that China is very interested in the Pratt and Whitney PW 1120 engine (single engine, thrust 9,000 kg) designed for fighter aircraft; hence, one can deduce that China is already planning the development of a new fighter aircraft following the F-8. The appearance of the F-8 shows evidence of the modernization of the Chinese Air Force and the rapid development of China's aeronautical technology.

3012

CSO: 4008/397

APPLIED SCIENCES

4-BIT MICROPROCESSOR CAPABILITIES, APPLICATIONS DESCRIBED

Beijing DIANZI JISHU YINGYONG [ELECTRONICS APPLICATIONS] in Chinese  
No 5, 25 May 85 pp 40-45

[Article by Miao Xiaosheng [4924 2556 0524], Wenzhou Electronics Research Institute: "Functions and Applications for 4-Bit Microprocessors"]

[Text] Editor's note: The 4-bit microprocessor is the ancestor of microprocessor families, which continue to develop dramatically. Because the structure of the 4-bit microprocessor is simple and it is functionally flexible, and because it has a high performance to price ratio, it is widely used in household electronics, public electronic devices, industrial control devices, and various instruments and devices. The 4-bit microprocessor has both suitable data processing power and a definite controlling capability, and it is both highly universal and yet possessed of an appropriate specificity. It constitutes 70 percent of the world's microprocessor sales, and those sales account for 50 percent of money earned from microprocessor sales.

Production of China's 4-bit microprocessor circuits has currently reached the level of foreign developmental chips in the early 1980's. There are already several hundred units in China that have taken up applications with 4-bit microprocessors, and domestically produced 4-bit microprocessor circuits (Plant #878 and Shangwu Plant #14 production) can already more or less fulfill domestic requirements.

In order to disseminate general knowledge about the 4-bit microprocessor and resolutely broaden applications for domestically produced microprocessors in restructuring China's traditional industry, this publication begins this issue in publishing the technical discussion called "Functions and Applications for 4-Bit Microprocessors," written by electrical engineer Miao Xiaosheng, of the Wenzhou Electronics Research Institute. This discussion runs in total to from 100,000 to 120,000 characters, divided into eight topics, the subject of each as follows:

The first topic: A brief history of the development of 4-bit microprocessors and their performance characteristics.

The second topic: The hardware structure of domestically produced 4-bit microprocessors.

The third topic: The command system for 4-bit microprocessors.

The fourth topic: Beginning program design for 4-bit microprocessors (part 1).

The fifth topic: Beginning program design for 4-bit microprocessors (part 2).

The sixth topic: Four-bit microprocessor application examples (part 1).

The seventh topic: Four-bit microprocessor application examples (part 2).

The eighth topic: The development process and tools for 4-bit microprocessors.

We welcome readers' opinions on the content of this series of discussions to help us constantly improve results from the task at hand.

The First Topic: The Development of 4-Bit Microprocessors and Their Performance Characteristics

#### I. The Development of 4-Bit Microprocessors

The world's first microprocessor was the 4-bit 4004 developed by the American Intel Corporation in 1971. It was designed especially by Intel for the needs of a Japanese desk calculator company. The next year they released the 8-bit 8008, which was a controller for a CRT terminal designed by the DTC Company. The flexibility of the design led to general use, which began the developmental process that changes with each passing day.

In the mainstream of initial microprocessor technology are various well-known representative 8-bit microprocessors in common use, such as the 8080, the M6800, and the Z80. These chips have only a CPU, and to construct an application system one must still provide other circuits. But they are very adaptable, and when constructing applications systems the selectivity of functions and expansibility are very convenient, and rapidly developed systems software brings a great deal of support to the development of new applications fields. When one adds the low cost, one can see how in a few short years they have penetrated nearly every area. And later the high performance 16 and 32 bit processors were developed, like the 8086, the M68000, and the Z8000.

In nearly the same time period, developments in microprocessor technology produced a new trend to attract people's attention, that is, putting everything on one microprocessor chip and specialization in microprocessors. This is a natural consequence of developments in LSI. Improvements in integration can not only contain all the functions of a CPU, but can also contain necessary memory and I/O controlling circuits. Serving an innovative function in this aspect was the TMS-1000 released by the American Texas Instruments, Inc., in 1975. This was a single chip 4-bit microcomputer. Over a year later, several firms sought to copy it, Japan's Fujitsu, Hitachi, Toshiba, Sharp, Matsushita, and Nippon Denki, and the American Rockwell Corporation quickly put out their own monolithic 4-bit series. Various 8-bit monolithic processors also poured forth, the most well-known among which were the Intel MCS-48, the UPI-41, Fairchild's F8, Nippon Denki's  $\mu$  COM 83 and 84,

etc. Texas Instruments even put out a 16-bit monolithic microprocessor, the TMS-9940. Table 1 shows the developmental process of the early microprocessor technology.

Table 1

year		model	development unit
1971	4004	4-bit micro.	Intel
1972	8008	8-bit micro.	Intel
1973	8080	8-bit micro.	Intel
1974	M6800	8-bit micro.	Motorola
1975	TMS-1000	mono. 4-bit micro.	Texas Instruments
1976	Z80, 8085	8-bit micro.	Zilog, [Intel]
1977	8048	8-bit monolithic	Intel

What we mean by a monolithic microprocessor is that on a single chip there is not only a CPU device, but also program memory (ROM), data memory (RAM), input/output channels, etc., which provide all the basic functions of a computer in a monolithic circuit. As is easily seen, in the aspects of cost, efficiency, size, etc., the monolithic circuit has many advantages over multi-chip systems. Therefore, in recent years monolithic microprocessors have developed extremely quickly, the rate of their growth greatly surpassing general purpose 8-bit microprocessors to become a new branch of the microprocessor family. In another aspect, because memory and I/O channels are fixed on the chip, its functions cannot avoid being limited, which has led to this characteristic of specialization for monolithic microprocessors.

Four-bit microprocessors can at one time parallel process (operations or transmission) 4-bit binary coded data, that is, a word length of 4 bits. Therefore, the circuits contained in the CPU section would be relatively fewer, due to which specialization appeared early. Since 1975 4-bit microprocessors have been constructed completely monolithically. Table 2 shows the numbers of main series and types of international 4-bit monolithic microprocessors.

Table 2

	1979	1981	1982	1983
number of 4-bit series	15	26	44	53
number of 4-bit types	113	172	249	305

## II. The Characteristics of 4-Bit Microprocessors

In comparison with the 8-bit microprocessors with which people are familiar, 4-bit microprocessors have their own unique characteristics. To a great degree, these characteristics are because of the word length (4 bits) and the requirements of applications, that is, in structure and requirements. We give a brief description below:

**1. Program Memory (ROM)** ROM on the chip is used to store the user's program. Programs for 4-bit microprocessors are specialized, that is, they are specially designed for a certain purpose. A 4-bit microprocessor in which a special program has been written into the ROM is actually a specialized circuit on a chip, for example, calculators or the controller circuit chips for washing machines or refrigerators, etc. The word length in ROM is not necessarily fixed at eight bits as it is with 8-bit microprocessors, but is arbitrarily designed by the chip designer according to the structure and requirements of the instruction system, generally between 8 and 12 bits (with 8 bits most often). The capacity of ROM is generally from 512 bytes to 4 K bytes. In order to improve instruction efficiency, single byte instructions can effect program jumps, ROM is always paged, usually with 64 bytes per page, that is, addresses within a page (PC low order addresses) are 6 bits. Because a nested series of subroutine calls is generally not many, the software stack technique is not usually needed, but rather the hardware stack method is used, that series being between 1 and 5.

**2. Data Storage (RAM)** RAM is used to store various data awaiting processing, and is therefore both readable and writeable. Obviously, the word length of each RAM unit in a 4-bit microprocessor is 4 bits binary coded. The capacity of RAM, then, is generally between  $32 \times 4$  and  $256 \times 4$ . To improve the efficiency and flexibility of data transfer instructions as much as possible, a segmented method is used for RAM addressing, which can be divided into 2 or 3 segments according to capacity. The lower section is usually 4 bits, that is, addressing  $2^4 = 16$  units. Relevant data transfer instructions all have powerful composite functions, as at the same time that they complete data transfer they can undertake various revisions of RAM addressing. There are also three bit operation instructions that can set or reset each bit in a RAM unit or test for conditional operations, and that can be used to construct various special index bits, which makes programs very flexible. It can be seen from all this that RAM and ROM are completely independent, their respective address and data lines not being related.

**3. Input/Output Circuits** Input/output circuits for the 4-bit microprocessor show even more clearly the specialized characteristics, and generally include: (1) 4-bit parallel output ports, 4-bit parallel input ports, and 4-bit parallel bi-directional ports. These general purpose ports can be one or many, and besides use in communication with data outside the computer, they can also be used as control signals. (2) Scan output ports. Used to make up keyboard and display scanning signals, the number of lines can be up to 16, which often use the lower 4 bits of the RAM address for addressing. (3) PLA (Programmable Logic Array) decoding output port. For example, decode the 4-bit data in the accumulator into 16 (or adding a status bit can decode into 32) eight segment graphics output. One can also link together the 8-bit data

in the accumulator and the RAM for direct output. Output ports generally have driver capabilities and can directly drive LED's, fluorescent character display tubes, or LCD displays. Therefore, interfacing to displays is very easy. (4) Serial input/output ports. These can change off-chip data into on-chip 4-bit parallel data, or change on-chip parallel data into serial data output. Ordinarily, the on-board clock is used for synchronization, although external clocks are used to synchronize as well.

**4. Control Circuits** The majority of 4-bit microprocessor application systems have real time control requirements, so consequently the following control functions are usually on-chip: (1) Timer/counter. Comprised of multistage frequency dividers, the signal source can be determined by the instructions. When it is determined to be an on-chip clock it is a timer, the settings of the high order bits can be pre-set by instructions so that the time intervals can be programmed; when determined to be off-chip pulses that is a counter, used to count the frequency of external events. When the timer/counter has counted full it can be tested by instructions or can generate an interrupt signal. (2) Interrupt functions. This includes peripheral interrupts and timer/counter interrupts, and provides an effective real time service function. (3) Special control circuits, like the printer controller interface for the SM-2, are very effective when controlling peripheral interrupts.

**5. Other High Level Specialty Circuits** As, for example, circuits for A/D, D/A, PLL (phase locked loop), and sound integration. For these, analog circuits must be dropped into the chip, the techniques for which are complicated. This is a new technique for recently developed 4-bit computers, but greatly strengthens the capabilities and further expands the fields of application for 4-bit microprocessors.

**6. Multiple Variety Serialization** To improve the performance to price ratio, it is best to adapt to system requirements, and 4-bit microprocessors generally develop in series diversification, as with the Japanese Matsushita MN1400 series of 4-bit microprocessors, which has reached 39 different kinds. Four-bit microprocessors in the same series are nearly the same regarding hardware structure and instruction sets, differing only in the aspects of ROM and RAM capacity, number of I/O channels, manufacturing techniques (PMOS, NMOS, CMOS), and the presence or absence of specialty circuits. In this way the user can choose the most appropriate kinds during development based on capacity.

**7. Software Characteristics** Because the capacity of ROM is smaller, in order to improve program efficiency and to realize the requirements of real time control, programs for 4-bit microprocessors are generally written in assembly language, and we have not yet seen 4-bit microprocessors programmed in high level languages. What is finally written into the ROM is merely the user's special program, not needing system software like an operating system or a monitor program. Therefore, software compatibility, maintainability, and transportability is not as obvious as for 8-bit computers. This has created a situation of great diversification within 4-bit microprocessor series and much activity among companies, unlike the situation with 8-bit microprocessors, where the effect of software compatibility has created a situation where a few primary devices lead the field.

In general, the 4-bit microprocessor has both suitable data processing capability and a certain ability to control; it is a monolithic circuit having both great universality and suitable specialization. Because it can only handle 4 bits of data at a time, its processing ability is not considered great, but for normal low speed applications it is more than enough, and is especially suited to decimal operations, because a one digit decimal number can be indicated as 4 bits of binary numbers. The on-chip special I/O controller circuits (like controller circuits for keyboards, display, and printers) greatly simplify peripheral interfaces, and the universality in design also allows it to flexibly adapt to an extremely broad range of applications requirements. Making it structurally monolithic allows the cost of 4-bit microprocessors to drop to the lowest levels. Abroad, each chip sells for only \$1.00 or \$2.00, or even less. These advantages allow the 4-bit microprocessor to attain the broadest application. Worth mentioning is that the Japanese are especially respectful of the 4-bit microprocessor, and nearly every corporation has developed its own 4-bit microprocessor series.

### III. Applications for 4-Bit Microprocessors

Areas for application of 4-bit microprocessors are extremely wide-ranging; they may be used in nearly all fields where processing speeds are not high, the quantity of data to be processed is not great, and where the handling process is not complicated.

The following list is of only a few typical examples seen in foreign publications and reports, but it is not difficult to see the characteristics and universality of application aspects.

1. **Household Electrical Equipment** Washing machines, mixers, air conditioners, microwave ovens, electric pans, electric fans, thermostats, and household clocks and timers.
2. **Public Devices** TV controllers, CB broadcast mixer, digital FM tuner, stereo sound systems, tone producers, electronic doorbell, electronic toys, recreation machines, and digital telephones.
3. **Commercial Equipment** Calculators, POS (sales terminals), ECR (electronic cash registers), electronic scales, gasoline pumps, elevators, ice cream machines, automatic phonographs, rental vehicle fee meters, and facsimile equipment.
4. **Industrial Control** Sewing machines, weaving machines, temperature controllers, programmable controllers, automatic ventilation equipment, gas heating furnaces, special counter/timers, building machinery, and agricultural machinery.
5. **Instruments** Oscilloscopes, power supplies, RLC test instruments, mixers, sphygmomanometers, medical instruments, optical instruments, and laboratory instruments.
6. **Administrative Machinery** Copiers and desk-top printers.

## 7. Safety Systems Electronic door locks, weather warnings, and ID systems.

### IV. Introduction to a Typical 4-Bit Microprocessor-- the COP400 Series

Although the diversity in foreign 4-bit microprocessor series is very great, structurally and functionally they are largely the same. We briefly discuss below a typical microprocessor model-- the American National Semiconductor, Inc., COP400 monolithic 4-bit microprocessor series. There are 13 models in this series, 3 models of which are developmental chips with an external ROM interface, with 40 base pins. The 10 other models are batch produced monolithic microprocessors, with from 20 to 28 base pins. The hardware structure and instruction sets for all models are nearly identical, only the extent of capabilities differs. Table 3 is an overview of functions of the COP400 series:

The COP420 is the main processor in the COP400 series, and its structural schematic is as in figure 1. We discuss below its chief functions.

#### 1. Program Memory

The capacity of program memory (ROM) is 1024 bytes, with a word length of 8 bits. As said above, the ROM can structurally be divided into 16 pages, each page having 64 bytes. Instructions are generally what is stored in ROM bytes, but it can also be program data or address data (when jumping to instructions).

ROM is addressed by the 10-bit program counter (PC), and the PC is similarly divided into two parts: page address  $P_U$  (high 4 bits) inter-page address  $P_L$  (lower 6 bits). Actually, paging in the ROM is determined by the PC paging, and is also reflected in the jump instructions JP, JSRP, JID and the immediate data instruction LQID. In each instruction cycle a new address value is sent to the PC, generally 1 is added to the PC, so to fetch and execute is the instruction in the next address of the ROM. But what is sent in during execution of the jump instruction is the address data in the instruction, thus what is fetched is the instruction in the next address, which accomplishes a program jump. The three first-in last-out hardware stacks SA, SB, and SC provide the capability for three-level subroutine nesting.

Fetching, decoding, and executing instruction words in ROM is accomplished through on-chip instruction decoding, control and leapfrog logic circuits.

Table 3 Overview of COP400 Series Functions

performance /		without ROM device			monolithic microprocessor									
device		402	402M	402L	410L	411L	420	420L	420C	421	421L	421C	444L	445L
memory	ROM X 8	external EPROM			512		1024		1024		1024		2048	
		1024 2048												
	RAM X 4	64		128	32		64		64		64		128	
input/ output	input port	4			0		4		0		4		0	
	bi-direct.													
	3 state I/O	8			8		8		8		8		8	
	bi-direct I/O	4			4	3	4		4		4		4	
	output ports	4			4	2	4		4		4		4	
	serial I/O & extern. act. counter	present			present	present	present	SIO	present	SIO	present	SIO	present	present
general	interrupts	yes	no	yes	no		yes		no		yes	no	yes	no
	stack series	3			2		3		3		3		3	
functions	micro bus	no	yes	no	no		yes	no	yes		no		no	no
	instruction duration (ms)	4		16	4.5 ~ 6.3		4	16		4	16		16	
power source/ package	p.s. volt (V)	4.5 ~ 6.3		4.5 ~ 9.5	16		4.5 ~ 6.3	4.5 ~ 6.3	2.4 ~ 6.0	4.5 ~ 6.3	4.5 ~ 6.3	2.4 ~ 6.0	4.5 ~ 6.3	
	supply (mA)	30		15	5		30	8	△	30	8	△	11	
	pack. leads	40		24	20		28		24		28		24	

△: high speed: 800 microamps, slow speed: 35 microamps, waiting: 15 microamps

## 2. Data Memory

The capacity of data memory (RAM) is 256 bits, organized into 4 registers, each register having 16 cells, with a cell length of 4 bits. RAM addressing is accomplished by the 6-bit B register, the higher 2 bits Br used to select one of the 4 registers, and the lower 4 bits Bd selecting one of the 16 cells. The RAM cell M(B) selected can execute various data transfer operations under instruction control: M --> A, A --> M, A <--> M, M --> Q, Q --> M, L --> M,

etc. (A, Q, and L are internal registers, detailed below). There are also the two double word direct instructions LDD and XAD, with 6-bit direct addresses in the instructions, which can address directly without going through the B register for the  $M \rightarrow A$  and  $M \leftarrow A$  operations.

Contents of the Br register can also be sent to the D register output off-chip.

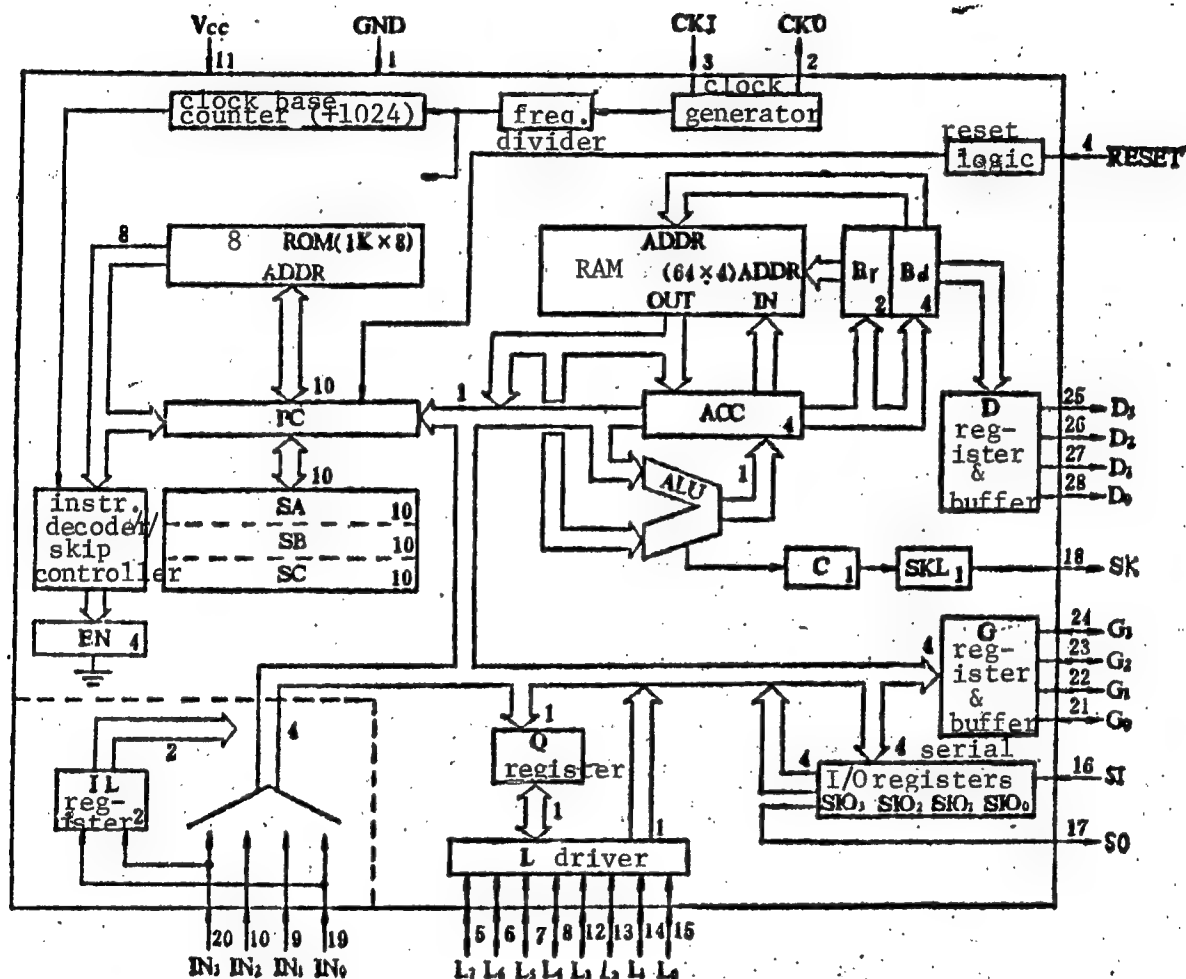


Figure 1. Structural Schematic of the COP 420

### 3. Internal Logic

(1) **Register (accumulator)** is the most important internal register. It is the source and target register for most I/O operations, arithmetic operations, and data storage access operations. It uses the segmented method when doing data transfer with other registers of words longer than 4 bits. If it is with the 6-bit B register, each time it will load either the Br part or the Bd part. With the 8-bit Q latch and L drivers, it is used by linking A and M(B), one instruction completing 8-bit data transfer in one operation. This kind of 8-bit transfer capability allows this processor to communicate conveniently through the L port with 8-bit processors, creating a so-called "Microbus" interface.

(2) **Four-bit Adder** executes all arithmetic and logical operations, results of which are placed in the A register. During operations it also sends out the carry bit to the 1-bit C register, which usually signifies an arithmetic overflow. The C register also coordinates the XAS instruction and the EN register to control SK output (described later).

(3) **General Input Ports  $IN_3$  to  $IN_0$**  are 4 bits for input interfacing. In the microbus operation mode,  $IN_1$ ,  $IN_2$ , and  $IN_3$  are input ports for, respectively, reading, chip select, and write select signals.

(4) **D Register and Ports** are 4-bit parallel general output channels. In addition to A, they can accept and transmit the contents of the Bd register, and at this time D is usually the scanning signal for keyboard and display.

(5) **G Register and Ports** are 4-bit parallel bi-directional channels. In the microbus operation mode,  $G_0$  is the output port for an interrupt request signal.

(6) **Q Register** is an internal 8-bit latch, which can latch 8-bit data from A and M, or can send it back. It can also accept 8-bit direct data from the ROM. Its mode of operation is controlled by  $EN_2$  in the pattern register, and when  $EN_2 = 1$ , Q sends to the output of L. In microbus operation mode, in the select channel signal function, Q accepts the 8-bit data from the L port.

(7) **L Driver and Ports** when initially in output mode can output the contents of the Q latch. When initially in input mode, it is in a high resistance state. The contents of L can also be directly sent to A and M. L has a selectable high current driver mode, and when at high level the greatest output current can reach 12 mA, so it can be directly connected to LED segment signal terminals.

(8) **SIO Registers** can be 4-bit serial in serial out registers or binary counters, and working mode selection is controlled by pattern register EN. Its contents can be exchanged with A, and therefore can be used to input or output continuous serial data flow. The SIO can also provide an additional parallel output port as long as one is connected at the S0 terminal or several serial ins go out in parallel through the shift register.

The XAS instruction sends C to the SKL latch, and in counter mode SK outputs the contents of SKL (i.e., C); in shift register mode SK outputs the AND signal for SKL and the clock.

(9) **Pattern Register EN.** The contents of EN are immediately determined by the immediate numeric instruction LEI. Each bit in EN separately controls on-chip functions of particular components.

EN<sub>0</sub>: determines mode of operation for SIO register.

When EN<sub>0</sub> is 1, the SIO becomes an asynchronous binary counter, and whenever there is a trailing pulse at the S<sub>1</sub> input terminal, the counter value is reduced by one. The pulse width must not be less than two instruction cycles. SK outputs the value of SKL. SO outputs the value of EN<sub>3</sub>.

When EN<sub>0</sub> is 0, the SIO is a serial shift register and in each instruction there is one shift left. Data from the SI terminal enters the lowest bit of the SIO and the highest bit of the SIO is sent to the SO. SK is a logic controlled clock.

EN<sub>1</sub>: is the interrupt allowed signal. When EN<sub>1</sub> is 1 an interrupt is enabled, allowing IN<sub>1</sub> to act as an interrupt input terminal; when EN<sub>1</sub> is 0, interrupts are disabled.

EN<sub>2</sub>: L driver port controlled. When EN<sub>2</sub> is 1, L outputs data from Q; when EN<sub>2</sub> is 0, it sets L in a high resistance input state.

EN<sub>3</sub>: together with EN<sub>0</sub> controls SO output. When EN<sub>0</sub> is 1, the value of EN<sub>3</sub> is the SO output; when EN<sub>0</sub> is 0, if EN<sub>3</sub> is 1, then SO acts as a serial output terminal for the SIO; if EN<sub>3</sub> is 0, then SO is always 0.

Table 4 shows the control of serial input/output functions.

Table 4

EN <sub>3</sub>	EN <sub>0</sub>	SIO	SI	SO	SK
0	0	shift register	input for	0	if SKL=1, SK=CLOCK
1	0		shift register	serial output	if SKL=0, SK=0
0	1	binary counter	input for	0	SK = SKL
1	1		binary counter	1	

#### 4. Internal Timer

There is an on-chip 10-bit binary counter on the COP420 that divides and counts instruction cycle pulses, and after a full count value of 1024, the highest bit overflows to set a bit on the marking flip-flop. With the SKT

instruction one can test this mark, and if it is 0 (not yet finished counting), then the next instruction can be carried out; if it is 1 (there is an overflow), then the next instruction is bypassed in execution and the marking flip-flop is reset. In this way one can form subroutines that execute by time discrimination.

This function provides an effective internal time base that can be used to make a clock or to execute real time processing. For example, if we use a 2.097 MHz crystal as the oscillator for the COP420, then the instruction frequency will be 131 KHz (crystal frequency +16), counter output pulse frequency is 128 Hz, and all that is needed is for the SKT instruction to test and count to the overflow point of 128 times, at which time it will be a 3 second signal, and with further attention one can get clock signals for minutes, seconds, the date, etc.

## 5. Interrupt Functions

IN<sub>1</sub> is the interrupt signal input terminal. The interrupt process is as follows:

(1) interrupt receives its condition:

a. EN<sub>1</sub>=1, that is, interrupt enabled.

b. there is a negative skip pulse of at least the duration of two instruction cycles at the IN<sub>1</sub> terminal, it then generates an interrupt request signal of sufficient width.

c. the current instruction finishes execution.

d. all successive jump instructions and LBI instructions have finished execution (for example, if the main program executes a JP instruction to jump to another JP instruction, only after that second JP instruction has executed will the interrupt be accepted).

(2) After the interrupt has been accepted, the next contents of the program counter will be pushed onto the stack, which causes the stack contents to transfer in order from a higher level to a lower level (PC+1-->SA-->SB-->SC), the contents of the lowest level stack register SC being dropped. At the same time, the program counter is set to OFF (the last byte of the third page), EN<sub>1</sub> is reset, prohibiting follow up interrupts.

(3) After an interrupt has been accepted the state of program leapfrog logic is preserved. When the interrupt service routine has finished the program pops the stack. In interrupt service routines subroutines cannot be used together with the QID instruction (this instruction also uses the stack), because at the return from the subroutine it will pop the leapfrog state and will consequently disrupt proper operation of the interrupt service routine.

(4) The first instruction in the interrupt service routine at the OFF address must be a NOP (null operation) instruction.

(5) Before the interrupt service routines conclude, they closely depend upon whether the RET instruction has set a LEI instruction to reinitiate an interrupt.

## 6. Microbus Interface

The COP420 has a selectable function that allows it to be used as a peripheral microprocessor device to undertake data communications with the host computer. At this time the general input terminals  $IN_1$ ,  $IN_2$ , and  $IN_3$  constitute signal lines for read select channel, chip select, and write select channel.  $IN_1$  is RD, which when low will cause the contents of the Q latch to be output through the L port.  $IN_2$  is CS, and when low the COP420 is selected, and only at this time can the RD and WR signals be used.  $IN_3$  is WR, which when low will cause the data in the L port to be written to the Q latch. GO becomes INTR, that is, "ready" to output, which is reset by the WR line write signal, providing asynchronous "handshaking" capabilities between the COP420 and the host computer. Figure 2 is a schematic of the microbus interface.

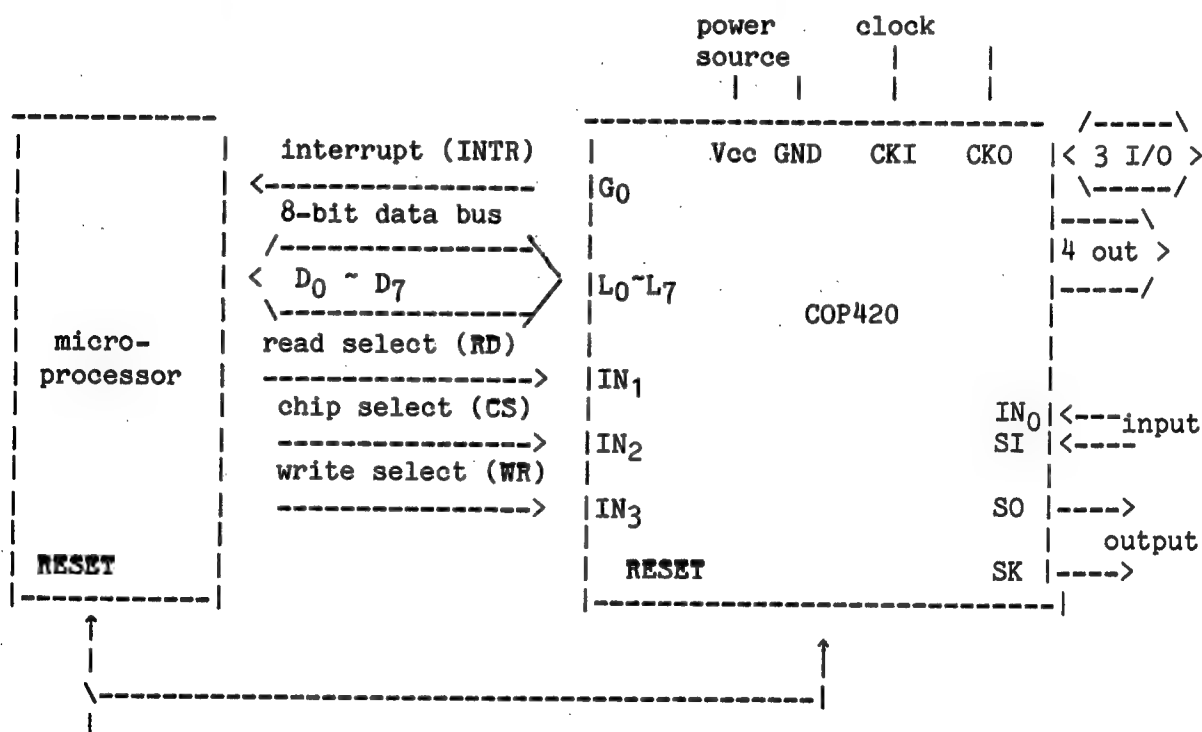
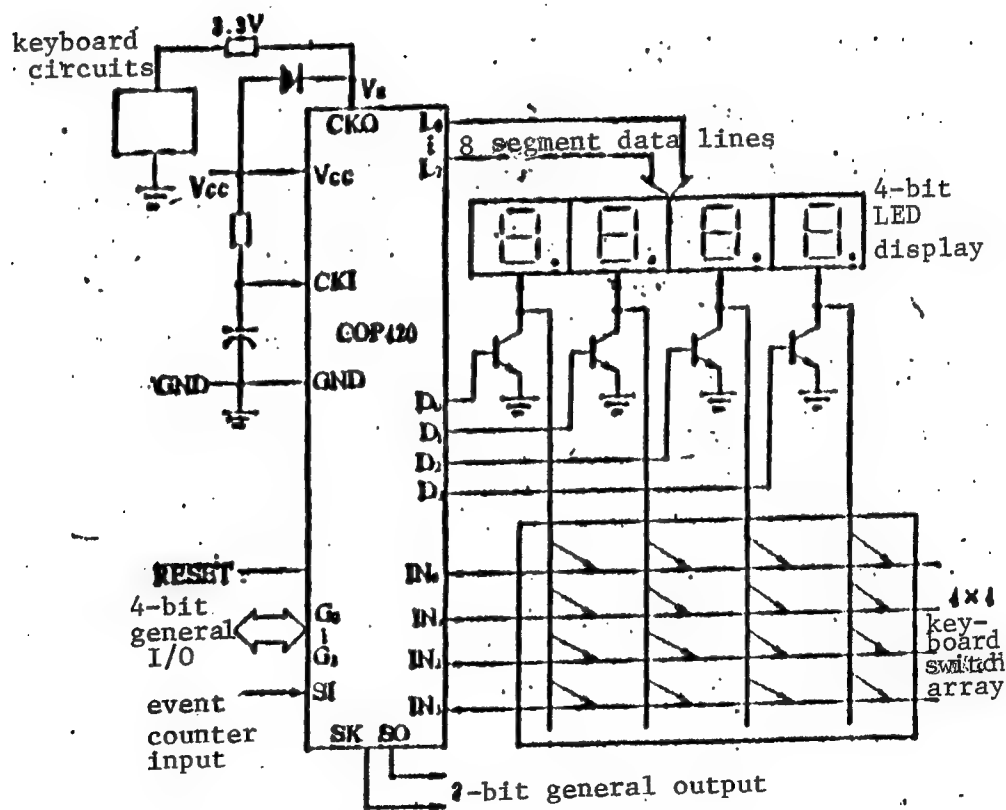


Figure 2 Microbus Interface Schematic

Aside from the above functions, the flexibility of the COP420 is also manifested in the programmability of its lead pins (especially the input/output terminals). For example, the L port has the four selectable modes of standard output, open output, LED direct driver output, and tri-state push-pull output. The user can select one according to the actual application circuit requirements, give the selected number and the ROM program over to the component factory to make a mask-board, and then you can have the function you desire. The so-called Microbus is one of these functions that can be selected.

There are few peripheral circuits required when using the COP420 to make a simple application system. Figure 3 is a general purpose controller with 4-bit LED nixie tubes and a multi-contact 16 key keyboard, as well as providing 7 control lines, by which may be effected control with differing goals.



\*SI, SO and SK may also be used for serial I/O

Figure 3. A COP420 General Controller

Development of the COP420 will use the corresponding development chip, the COP402, functions of which are completely the same, but 12 base pins have been added, providing compound address/instruction signals (must be separated externally). This consequently allows an external EPROM or RAM as program memory and for debugging of applications programs.

The COP400 series has already been selected as outstanding models of microprocessors, and in China two 4-bit microprocessor factories have already begun advanced production of the COP400 series chips, and are undergoing testing in household appliance applications. I believe that not long from now there will be a new wave of 4-bit microprocessor applications.

(to be continued)

12586

CS0: 4008/1063

APPLIED SCIENCES

ULTRALIGHT HYDROPLANE MAKES SUCCESSFUL TRIAL FLIGHTS

OW11306 Beijing XINHUA in English 1247 GMT 11 Sep 85

/Excerpt/ Changchun, 11 Sep (XINHUA)--China's first ultralight hydroplane has successfully made 11 trial flights this month on Songhua Lake near Jilin city, Jilin Province, according to local officials.

Manufactured in Shijiazhuang city, Hebei Province, the hydroplane weighs 123 kg.

With two glass-fiber reinforced plastic pontoons, it can land on and take off from rivers and lakes.

The plane can fly at 82 km per hour at an altitude of 3,000 meters. It can be used for flight training, photographing, pesticide spraying, and mineral prospecting.

The production cost is about 18,000 yuan.

CSO: 4010/168

APPLIED SCIENCES

MARITIME PATROL AIRCRAFT PASSES TECHNICAL APPROVAL

OWO41316 Beijing XINHUA in English 1213 GMT 4 Sep 85

/Text/ Beijing, 4 Sep (XINHUA)--China's first domestically made maritime patrol plane passed technical approval here today.

An official of the aviation industry said this would provide an important means for marine service in China's national economy.

The official said the patrol plane is equipped with advanced navigation and radar systems. It can be used to inspect marine pollution, carry out salvage operations, service offshore drilling rigs, and scout fish shoals.

The plane was manufactured by the Shaanxi transport plant on the basis of the Yun-8, the largest transport plane that China has ever built. Capable of flying 10 hours on end, the plane has a maximum patrol radius of 3,500 km.

CSO: 4010/168

APPLIED SCIENCES

MATHEMATICAL MODEL OF THE DYNAMIC RESPONSE OF THERMO-REGULATING IN 200 MeV  
LINEAR ACCELERATOR

Hefei ZHONGGUO KEXUE JISHU DAXUE XUEBAO [JOURNAL OF CHINESE UNIVERSITY OF  
SCIENCE AND TECHNOLOGY] in Chinese Vol 15, No 2, Jun 85 pp 217-222

[Article by Hu Defang [5170 1793 5364], and Ouyang Xiantai [2962 7122 0752 3141]]

[Text] I. Introduction

A 200 MeV electron linear accelerator is used as the injector for the 800 MeV electron synchrotron. The traveling wave cavity of the linear accelerator is a  $2\pi/3$  model equal-impedance, disk-loaded waveguide. The power loss inside the waveguide attenuates exponentially along the length of the accelerator (in the x direction)[1].

In order to keep the accelerator in its optimum operating condition, it is necessary to maintain a constant temperature in the acceleration chamber so that the resonant frequency remains unchanged. However, to keep the temperature constant in the acceleration chamber, it is essential to maintain constant temperature both spatially and temporally. To maintain constant temperature spatially depends on the structural design of the cooling system for the acceleration chamber; to maintain constant temperature temporally can be accomplished by designing a regulating system based on the calculated dynamic and static characteristics of the regulated parameters.

On the basis of the structural design and the parameters of this linear accelerator, we have established a set of partial differential equations for the thermo-variables. By solving the partial differential equations using Laplace transform, we have derived a mathematical model of the distributed parameter dynamic response of the 200 MeV linear accelerator.

## II. Basic Assumptions

To simplify the problem, we have made the following assumptions:

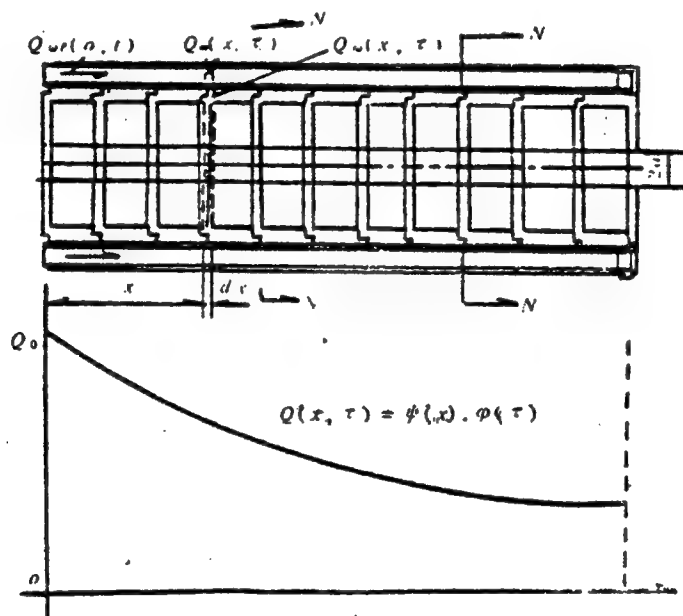
1. The temperature and velocity of the coolant are uniform over the tube cross-section.
2. The temperature is approximately uniform over a cross-section of the waveguide (calculations of the three-dimensional temperature field show that the temperature gradient is very small).

3. The axial heat conduction of the waveguide and the coolant can be neglected; this is a reasonable assumption when the Peclet number is greater than 100.
4. The physical parameters of the waveguide and the coolant are assumed to be constant within the operating temperature range.
5. The coefficient of heat transfer between the waveguide and the coolant is assumed to be a constant which does not vary with time or space within the operating temperature range.
6. The outer surfaces of the waveguide and the cooling tubes are assumed to be adiabatic; heat loss into the air is neglected.

### III. Mathematical Model of the Dynamic Response<sup>[2,3,4]</sup>

The structure of the waveguide is as shown in Figure 1.

Figure 1. Structure of the Waveguide



Consider an infinitesimal element  $dx$  at distance  $x$ , one can write the following dynamic thermal equilibrium equation for the cavity wall:

$$\begin{aligned} \theta(x, \tau) \cdot F_w \cdot dx - K \cdot A [\theta_w(x, \tau) - \theta_c(x, \tau)] dx \\ = C_w \cdot \rho_w \cdot F_w \cdot dx \frac{\partial \theta_w(x, \tau)}{\partial \tau} \end{aligned} \quad (1)$$

For the cooling water, the following dynamic thermal equilibrium relation holds:

$$C_w \cdot \rho_w \cdot F_w \cdot dx \frac{\partial \theta_w(x, \tau)}{\partial \tau} + u \cdot C_w \cdot \rho_w \cdot F_w \cdot dx \frac{\partial \theta_w(x, \tau)}{\partial x} = K \cdot A \cdot [\theta_m(x, \tau) - \theta_w(x, \tau)] dx \quad (2)$$

where  $x$  is the axial distance measured along the waveguide (m);  $A$  is the heat transfer area per unit length ( $m^2/m$ );  $K$  is the coefficient of heat transfer between the waveguide cavity wall and the cooling water ( $kcal/m^2 \cdot h \cdot ^\circ C$ );  $\tau$  is time (h);  $\rho_w$  is the specific gravity of the cooling water ( $kg/m^3$ );  $C_w$  is the constant-pressure specific heat of the cooling water ( $kcal/kg \cdot ^\circ C$ );  $F_w$  is the average cross-sectional area of the cooling water tubes ( $m^2$ );  $u$  is the velocity of the cooling water inside the tubes (m/s);  $\rho_m$  is the specific gravity of the waveguide material (oxygen-free copper) ( $kg/m^3$ );  $C_m$  is the specific heat of the waveguide material ( $kcal/kg \cdot ^\circ C$ );  $\theta(x, \tau)$  is the rate of heat generation per unit volume of the waveguide ( $kcal/m^3 h$ );  $\theta_m(x, \tau)$  is the waveguide temperature ( $^\circ C$ );  $\theta_w(x, \tau)$  is the temperature of the cooling water ( $^\circ C$ ).

The rate of heat generation per unit volume of the waveguide  $\theta(x, \tau)$  can be written as follows: [5,6]

$$\theta(x, \tau) = \varphi(\tau) \cdot \psi(x) = [\alpha_p \cdot \theta_0(\tau)] \cdot e^{-\alpha_p x},$$

where  $\psi(x)$  is the distance-dependent part of the function  $\theta(x, \tau)$ , and  $\theta_0(\tau)$  is the time-dependent part of  $\theta(x, \tau)$ ;  $\theta_0(\tau)$  is the rate of heat generation in the initial section of the waveguide ( $kcal/m^3 h$ );  $\alpha_p$  is the microwave power attenuation constant,  $\alpha_p = 0.354 m^{-1}$ .

Rearranging equations (1) and (2), we get:

$$\begin{aligned} \frac{\partial \theta_m(x, \tau)}{\partial \tau} + \frac{K \cdot A}{C_m \cdot \rho_m \cdot F_m} [\theta_m(x, \tau) - \theta_w(x, \tau)] \\ = \frac{\theta(x, \tau)}{C_m \cdot \rho_m} = \frac{\alpha_p \theta_0(\tau) \cdot e^{-\alpha_p x}}{C_m \cdot \rho_m} \end{aligned} \quad (3)$$

$$\frac{\partial \theta_w(x, \tau)}{\partial \tau} + u \frac{\partial \theta_w(x, \tau)}{\partial x} = \frac{K \cdot A}{C_w \cdot \rho_w \cdot F_w} [\theta_m(x, \tau) - \theta_w(x, \tau)] \quad (4)$$

Let  $a_1 = \frac{K \cdot A}{C_m \cdot \rho_m \cdot F_m}, \quad a_2 = \frac{K \cdot A}{C_w \cdot \rho_w \cdot F_w}, \quad a_3 = \frac{\alpha_p}{C_m \cdot \rho_m}.$

then equations (3) and (4) become

$$u \frac{\partial \theta_w(x, \tau)}{\partial x} + \frac{\partial \theta_w(x, \tau)}{\partial \tau} + a_1 [\theta_m(x, \tau) - \theta_w(x, \tau)] = 0. \quad (5)$$

$$\frac{\partial \theta_m(x, \tau)}{\partial \tau} + a_2 [\theta_m(x, \tau) - \theta_w(x, \tau)] - a_3 \theta_0(\tau) \cdot e^{-\alpha_p x} = 0. \quad (6)$$

with boundary conditions:  $\theta_{\bullet}(0, \tau) = \theta_{\bullet,1}(\tau)$ ,  $\theta_{\bullet}(0, \tau) = \theta_{\bullet,1}(\tau)$ .

and initial conditions:  $\theta_{\bullet}(x, 0) = 0$ ,  $\theta_{\bullet}(x, 0) = 0$ .

By applying Laplace transform to equations (5) and (6) with respect to  $\tau$ , we get:

$$u \frac{d\theta_{\bullet}(x, s)}{dx} + S\theta_{\bullet}(x, s) + a_1 [\theta_{\bullet}(x, s) - \theta_{\bullet}(x, s)] = 0. \quad (7)$$

$$S\theta_{\bullet}(x, s) + a_2 [\theta_{\bullet}(x, s) - \theta_{\bullet}(x, s)] - a_1 e^{-a_1 x} Q_1(s) = 0. \quad (8)$$

with boundary conditions:  $\theta_{\bullet}(0, s) = \theta_{\bullet,1}(s)$ ,  $\theta_{\bullet}(0, s) = \theta_{\bullet,1}(s)$ .

and initial conditions:  $\theta_{\bullet}(x, 0) = 0$ ,  $\theta_{\bullet}(x, 0) = 0$ .

Then applying Laplace transform to equations (7) and (8) with respect to  $x$ , we get:

$$u p \theta_{\bullet}(p, s) - u \theta_{\bullet,1}(s) + S\theta_{\bullet}(p, s) + a_1 [\theta_{\bullet}(p, s) - \theta_{\bullet}(p, s)] = 0. \quad (9)$$

$$S\theta_{\bullet}(p, s) + a_2 [\theta_{\bullet}(p, s) - \theta_{\bullet}(p, s)] - a_1 \frac{1}{p + a_1} Q_1(s) = 0. \quad (10)$$

Eliminating  $(p, s)$  from equations (9), (10) gives

$$\left( S + a_2 - \frac{a_1 a_2}{u p + S + a_1} \right) \theta_{\bullet}(p, s) = \frac{a_2 u}{u p + S + a_1} \theta_{\bullet,1}(s) + a_1 \frac{1}{p + a_1} Q_1(s) \quad (11)$$

Now, applying inverse Laplace transform to equation (11) with respect to  $p$ , we obtain:

$$\left( S + a_2 - \frac{a_1 a_2}{u} e^{-\frac{S+a_1}{u} x} \right) \theta_{\bullet}(x, s) = a_2 e^{-\frac{S+a_1}{u} x} \cdot \theta_{\bullet,1}(s) + a_1 \cdot e^{-a_1 x} Q_1(s). \quad (12)$$

From equation (12) we can derive the transfer functions for the regulating channel and the interference channel of the waveguide thermo-variables.

$$\frac{\theta_{\bullet}(x, s)}{\theta_{\bullet,1}(s)} = \frac{a_2 e^{-\frac{a_1}{u} x} e^{-\frac{x}{u} s}}{S + a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1}{u} x} \cdot e^{-\frac{x}{u} s}}. \quad (13)$$

$$\frac{\theta_{\bullet}(x, s)}{Q_1(s)} = \frac{a_1 e^{-a_1 x}}{S + a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1}{u} x} e^{-\frac{x}{u} s}}. \quad (14)$$

To facilitate analysis and verification, the approximation  $e^{-\frac{x}{u} s} \approx 1 - \frac{x}{u} s$  can be substituted in the denominators of equations (13) and (14) to yield:

$$\begin{aligned} \frac{\Theta_m(x, s)}{\Theta_{w1}(s)} &= \frac{a_2 e^{-\frac{a_1 x}{u}} e^{-\frac{x}{u} s}}{s + a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1 x}{u}} \left(1 - \frac{x}{u} s\right)} = \\ &= \frac{a_2 e^{-\frac{a_1 x}{u}} / \left(a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1 x}{u}}\right) \cdot e^{-\frac{x}{u} s}}{\left(\frac{1 + \frac{a_1 a_2 x}{u^2} e^{-\frac{a_1 x}{u}}}{a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1 x}{u}}}\right) s + 1} = \frac{K_1(x)}{T(x) \cdot s + 1} \cdot e^{-\tau(x) \cdot s} \end{aligned} \quad (15)$$

$$\begin{aligned} \frac{\Theta_m(x, s)}{Q_1(s)} &= \frac{a_2 \cdot e^{-a_1 p \cdot s}}{s + a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1 x}{u}} \left(1 - \frac{x}{u} s\right)} = \\ &= \frac{a_2 e^{-a_1 p \cdot s} / \left(a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1 x}{u}}\right)}{\left(\frac{1 + \frac{a_1 a_2 x}{u^2} e^{-\frac{a_1 x}{u}}}{a_2 - \frac{a_1 a_2}{u} e^{-\frac{a_1 x}{u}}}\right) s + 1} = \frac{K_2(s)}{T(x) \cdot s + 1} \end{aligned} \quad (16)$$

Equation (15) shows that the dynamic response of the regulating channel is a first-order inertial loop with a pure delay loop. Equation (16) shows that the interference channel is a first-order inertial loop.

#### IV. Conclusion

In order to verify the theoretical derivation, we have experimentally determined the response of the waveguide temperature at  $x = 1.345\text{m}$ ,  $\theta_m(1.345, \tau)$ , with respect to step variation in  $\theta_{w1}(\tau)$ ; from the experimental curve we computed the following:

$$\left[ \frac{\theta_m(1.345, s)}{\theta_{w1}(s)} \right]_{\text{experiment}} = 0.92 \frac{e^{-2.5s}}{50s + 1}.$$

By substituting  $x = 1.345\text{m}$  and the known structural dimensions and thermal parameters into equation (15), we obtain the following:

$$\left[ \frac{\theta_m(1.345, s)}{\theta_{w1}(s)} \right]_{\text{theory}} = 0.96 \frac{e^{-1.44s}}{50.14s + 1}.$$

It can be seen that the theoretical calculations are basically in agreement with experimental results; the small discrepancy is due to the primary measuring element and the pure delay and volume delay of the transducer. The good

agreement between theoretical and experimental results validates the proposed mathematical model.

Once a mathematical model of the dynamic response of the thermal variables is known, it can be used to design various regulating systems and to derive the system characteristics equation. From this the equation of the regulating process under different types of disturbances can be obtained and the performance of thermo-regulating can be determined.

Based on the analysis and calculations presented in this paper, a regulating system with serial stages is chosen as the main system for this project. To ensure high degree of precision of maintaining constant temperature, this system is supplemented by a pre-regulating system and a correlation regulating system. In order to satisfy this type of real-time, multi-purpose processing requirement, an intelligent MACSYM-350 monitoring and control unit is used to perform the functions of measuring thermal parameters, data processing, regulating and control.

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3012

CSO: 4008/396

APPLIED SCIENCES

BRIEFS

SONAR SHIP DOCKING DEVICE DEVELOPED--Beijing, 11 Sep (XINHUA)--A new aid to pilots bringing ships into port has been developed by scientists at the Institute of Acoustics of the Chinese Academy of Science. Experts approved the docking sonar device on Tuesday. The docking sonar has a microprocessor to handle the ship's speed, distance and angle of inclination to the shore to aid the pilot. Docking tests of big vessels at several ports in the past year proved that the equipment is reliable, better than imported types in terms of functions, automation and reliability, but costs only one-third as much. [Text] [Beijing XINHUA in English 0811 GMT 11 Sep 85 OW]

CSO: 4010/002

## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

### INSTITUTES OF AERONAUTICS AND ASTRONAUTICS REVIEWED

Beijing HANGKONG ZHISHI [AEROSPACE KNOWLEDGE MAGAZINE] in Chinese No 7,  
Jul 85 p 9

[Text] Shenyang Aeronautical Institute

The Shenyang Aeronautical Institute is a 4-year college established by the Ministry of Aeronautical Industry to train high-level engineering and technical personnel. It is located in Shenyang City.

The predecessor of the Institute was the Shenyang School of Aeronautics; in 1978, it was approved by the State Council to change its name to the Shenyang Aeronautical Institute.

The Institute occupies approximately 400 mu of land, and has 12,000 square meters of building space; its enrollment is 1,600. It has a team of faculty members who are experienced in teaching equipment and electronic teaching facilities.

The Institute has four departments and one section which offers fundamental courses, with seven different specialized disciplines.

The Aeronautical Engineering Department offers two specialized disciplines: aircraft manufacturing engineering, and aircraft engines.

The Mechanical Engineering Department offers two specialized disciplines: mechanical manufacturing techniques and equipment, and mechanical design and manufacturing.

The Electronic Engineering Department offers two specialized disciplines: computers and computer applications, and radio technology.

The Safety Engineering Department has one specialized discipline: safety engineering.

In 1985, the Institute will recruit 300 new students from 14 provinces, autonomous regions and municipalities.

The Institute has established a scholarship system to reward students who show outstanding academic, moral and athletic performance. After completing four years of study, students with good academic records are awarded the Bachelor's degree and are given the opportunity to apply for graduate study. The graduates are generally assigned positions in industrial and research organizations in their own disciplines; some remain at higher institutions to teach or to do research.

In recent years, the Shenyang Aeronautical Institute has trained nearly 1,000 scientific and technical personnel for the State. The future direction of the Institute is to establish an open-class and multi-level education system, and to develop the Institute into an education and research center of the aeronautical industry in the northeast region as well as a new, socialistic university with unique Chinese characteristics.

#### Nanchang Aeronautical Institute

The Nanchang Aeronautical Institute is a technical school for training high-level scientific and technical personnel for the aeronautical industry.

The institute has four departments: materials engineering, chemical engineering, mechanical engineering, electronics engineering, and a section which offers training for teachers. It has thirteen specialized disciplines: casting, forging techniques and tools, welding techniques and tools, metallic materials and heat treatment, corrosion and its prevention, environmental engineering, mechanical manufacturing techniques and tools, non-destructive inspection, electronic instruments and measuring techniques, mathematics (teacher training), physics (teacher training), chemistry (teacher training), and English (teacher training). The Institute is a four-year school and has been approved by the Ministry of Education to offer Master's degree in certain disciplines in 1985.

The main goal of the Institute is to provide a broad education with many specialized disciplines in order to improve the adaptability and flexibility of graduates in their job assignments. It also offers a comprehensive program of fundamental courses, specialized courses, laboratory work and design. The Institute has more than sixty laboratories which can accommodate all the experimental work required by the fundamental and specialized courses. It is also equipped with modern teaching and research facilities such as large, precision instruments, medium-size computers, microcomputers, practical systems for teaching languages, and closed-circuit television systems. The library of the Institute has a rich collection of books and journals to aid the students in their research. There is a large, fully-equipped training factory which provides an ideal training ground for the students.

The Institute is fully aware of the education policy of the Party and puts forth its best effort to provide a healthy environment for the students to grow, and to establish a team of competent faculty members. It frequently submits recommendations for qualified teachers to go abroad for tours and for advanced studies. It provides a good environment for teaching

and learning as well as a high standard of living for the teachers and students.

In 1985, the Nanchang Aeronautical Institute plans to recruit 420 new students nationwide.

3012

CSO: 4008/397

AUTHOR: CHENG Guocai [4453 0948 6846]

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TITLE: "Application of the Principle of Intermediate Orbit to the Explicit Guidance of Vehicle"

SOURCE: Beijing YUHAN XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 3, 31 Jul 85 pp 1-14

TEXT OF ENGLISH ABSTRACT: Application of the principle of intermediate orbit to the explicit guidance of vehicle is described in this paper. The first part discusses the method of explicit guidance of required-velocity, and obtains the formulation of guidance. The second part examines the utilization for outside information of vehicle to estimate the impact position error. Analyses show that a measurement of five points altitude in the free flight path, could possibly provide an estimate of the impact position error. All the results can be used to study interception, rendezvous and transfer orbit of satellite.

AUTHOR: LU Shouhua [7627 1343 5478]

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TITLE: "A Method for Numerical Generation of a Boundary-fitted Curvilinear Coordinate System"

SOURCE: Beijing YUHAN XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS]  
in Chinese No 3, 31 Jul 85 pp 22-30

TEXT OF ENGLISH ABSTRACT: This paper presents a method for numerical generation of a general curvilinear coordinate system, some coordinate lines in that system coincide with all physical boundaries in the two-dimensional field (herein called a "boundary-fitted coordinate system"). No matter what the form of physical boundaries, by using this procedure, the physical boundaries can be made to pass through the points of a finite differential grid and the numerical solution of a partial differential equation may be done on a rectangular field with a square mesh in the transformed plane without the need for any interpolation between the points of the grid. This method has been programmed with FORTRAN and has been applied to a simple two-dimensional converging-diverging nozzle (simply-connected regions) and an annular nozzle (multiply-connected regions). The computational samples show that the FORTRAN computer program is available.

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ORG: None

TITLE: "Some Approximate Functions of Thermo-gas-dynamic Performance of Liquid Propellant"

SOURCE: Beijing YUHAN XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 3, 31 Jul 85 pp 41-55

TEXT OF ENGLISH ABSTRACT: Based on certain theoretical knowledge and practical experience, some approximate analytical functions giving mathematical relationship among thermo-gas-dynamic parameters of liquid propellant are derived in this article.

These functions can be used in a wide range as interpolation and extrapolation formulae instead of tedious procedures recommended in past literature. Being continuous functions, they also may fill up rooms among discrete data in propellant performance handbooks. When used simultaneously with other equations of rocket or engine system in searching for optimal parameters, these functions may reduce the requirements of computer capacity.

AUTHOR: WEI Ketai [7614 0344 3141]  
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TITLE: "The Fracture Processes of Aluminium Reinforced By Bundling SiC Fiber To Be Monitored Through Acoustic Emission"

SOURCE: Beijing YUHAN XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS] in Chinese No 3, 31 Jul 85 pp 56-62

TEXT OF ENGLISH ABSTRACT: This paper is a research report in which an experimental study has been done on the fracture processes of aluminium reinforced by bundling SiC fiber to be monitored through acoustic emission.

Under the condition of the attenuation parameter being 1x6db and the ringing counting rate being 10<sup>4</sup>/Sec, the main mechanism of the acoustic emission of composite produced in the process of stretch is the fracture of SiC fiber.

Having compared the acoustic emission counting rate with the stress-strain curve of SiC/Al composite, pure aluminium and aluminium alloys, it was found that the curves of composites have only an exponentially increasing part and have none continuative part as pure aluminium and aluminium alloys. It shows that the fracture of SiC composites is brittle fracture, and SiC fiber is fractured gradually, but not simultaneously. This fracture process is one of the reasons for the dispersivity of strength of composite and its value is often lower than values calculated with ROM in most cases.

The acoustic emission counting rate increases rapidly when the strain is about 60-80 percent of the fracture strain. It shows that the composites have been in the unstable state in this case and will be broken immediately. It may be available for use as reference in structural design and product inspection.

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TITLE: "The Specific Strength and Specific Stiffness of Materials"

SOURCE: Beijing YUHANG XUEBAO [JOURNAL OF THE CHINESE SOCIETY OF ASTRONAUTICS]  
in Chinese No 3, 31 Jul 85 pp 80-85

TEXT OF ENGLISH ABSTRACT: It is widely recognized that the weight of a structural component is inversely proportional to the specific strength or the specific stiffness of the material selected and that these properties of materials are the most important parameters to be considered in materials selection.

The relation between a structural weight and strength or modulus of elasticity of materials under the conditions of a plate under tension, bending of a beam, a column subjected to compression and a hollow cylinder under internal pressure are analyzed and appropriate expressions for effective specific strength and effective specific stiffness are obtained. In general, these two parameters are given as  $\sigma^*/\rho$  or  $E_y/p$  ( $x, y \leq 1$ ) respectively, and are recommended as criteria for optimizing materials selection, in place of the specific strength  $\sigma/p$  and specific stiffness  $E/p$  applied commonly. Based on these expressions, it seems more effective to decrease the density of a material rather than to raise its strength or modulus of elasticity if weight is the critical problem for a design. From this point of view, it may be said that the history of developing aerospace materials is also the history of successively decreasing the densities of materials.

12949

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JPRS-CST-85-035

17 October 1985

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TITLE: "Synthesis of New Color Reagent Chlorophosphonazo-pB (CPA-pB) and Investigation of Its Color Reaction with Thorium in the Presence of Cationic Surfactant"

SOURCE: Beijing HUAXUE SHIJI [CHEMICAL REAGENTS] in Chinese Vol 7 No 2,  
28 Apr 85 pp 66-69

TEXT OF ENGLISH ABSTRACT: The synthesis and purification methods of a new color reagent, chlorophosphonazo-pB [2-(4-chloro-2-phosphonophenylazo)-7-(4-bromophenylazo)-1,8-dihydroxy-3,6-naphthalenedisulfonic acid (CPA-pB)], have been investigated. In a nitric and oxalic acid medium, CPA-pB combines with thorium in the presence of CTMAB to form a blue violet complex having high sensitivity. It shows a maximum absorption at 685 nm with molar absorptivity of  $3.5 \times 10^5 \text{ L} \cdot \text{mol}^{-1} \cdot \text{cm}^{-1}$ . Beer's law is obeyed in the range of 0-5  $\mu\text{g}/25 \text{ ml}$  for Th(IV). Most metal ions and  $\text{NH}_4^+$  do not interfere. Thus, CPA-pB not only has high sensitivity, but also good selectivity and is a superior color reagent for thorium. (Paper received on 10 August 1983.)

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TITLE: "Study of the Analytical Method of Crown Ethers--Rapid Gas-Liquid Chromatographic Analysis of Benzo-15-Crown-5"

SOURCE: Beijing HUAXUE SHIJI [CHEMICAL REAGENTS] in Chinese Vol 7 No 2,  
28 Apr 85 pp 99-101

TEXT OF ENGLISH ABSTRACT: A rapid gas-liquid chromatographic method has been developed and applied to the analysis of benzo-15-crown-5 in a reaction mixture. Crown ether samples were separated at 284°C on a column (200 x 0.4 cm) of 15 percent E-301 on silanized white support 102 with hydrogen flame ionization detection. Dibutyl phthalate was used as an internal standard. The title compound was quantified by using a calibration curve. (Paper was received on 1 September 1983.)

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TITLE: "Spectrophotometric Determination of Palladium (II) with HSPAF"

SOURCE: Beijing HUAXUE SHIJI [CHEMICAL REAGENTS] in Chinese Vol 7 No 2,  
28 Apr 85 pp 102-105

TEXT OF ENGLISH ABSTRACT: Synthesis of 1,5-bis (2-hydroxyl-5-sulfohenyl)-3-acetylformazan (HSPAF) and its spectrophotometric properties upon reaction with  $\text{Pd}^{2+}$  have been studied. The complex Pd-HSPAF with absorption maximum at 532 nm is formed in 0.24 N  $\text{H}_2\text{SO}_4$ -0.08 M  $\text{H}_2\text{C}_4\text{H}_4\text{O}$  medium. The composition of this complex is 1 to 1,  $\epsilon_{532} = 2.8 \times 10^4$ ,  $K_2 = 3 \times 10^6$ . Beer's law is obeyed in the concentration range of 0-70  $\mu\text{g}$  Pd/25 ml. The method can be applied to the spectrophotometric determination of palladium in C-Pd catalysts. (Paper received on 3 November 1983.)

9717  
CSO: 4009/1112

Computers

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TITLE: "Implementation of the PASCAL/TD Compiler for the CROMEMCO II"

SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY] in  
Chinese No 3, Jul 85 pp 40-46

ABSTRACT: The implementation techniques of the PASCAL/TD compiler in CROMEMCO II CDOS 02.17 were studied. As a one-pass compiler, the PASCAL/TD can translate a PASCAL source program into a CROMEMCO assembly language object program, together with which EDIT.COM, ASMB.COM, LINK.COM, and FORLIB.REL in the system form a PASCAL compiler system in CROMEMCO II CDOS 02.17. Compared with products of the same kind throughout the world, it has its own characteristics in the use of system resources and the conformity to the version defined by N. Wirth. (Paper received 5 November 1984.)

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CSO: 4009/1132

Computers

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TITLE: "Simple Key and Simple Normal Form"

SOURCE: Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese  
Vol 8 No 4, Jul 85 pp 262-267

ABSTRACT: A new normal form for relational databases called simple normal form (SNF) which lies between 3NF and BCNF is defined. This paper presents an algorithm that decomposes a relation scheme into a set of schemes  $\rho = (R_1, R_1, \dots, R_k)$  so that  $\rho$  has a lossless join and preservation of dependencies, and each  $R_i$  is in its simple form. (Paper received 20 January 1984)

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CSO: 4009/1131

## Computers

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TITLE: "On the Implication Problem for Sets of Embedded Multivalued  
Dependencies"

SOURCE: Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese  
Vol 8 No 4, Jul 85 pp 268-274

ABSTRACT: In this paper we intend to discuss some inference rules of FD, MVD  
and EMVD, and to investigate into the logical implicative problems of EMVD and  
MVD for relational database theory. It has been proved that a set of not full  
EMVD's cannot imply the nontrivial MVD's. (Paper received 21 September 1981;  
finalized 20 December 1984)

CSO: 4009/1131

## Computers

AUTHOR: QI Yongxin [3344 3057 2450]

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TITLE: "A Scheme for Method Base Management System"

SOURCE: Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese  
Vol 8 No 4, Jul 85 pp 275-280

ABSTRACT: This paper proposes an approach to the general solution for computer aid decision system: DB + MB, and describes the supplement to existing programming language with method base management facility, including a method definition sublanguage and an aid learning sublanguage. (Paper received 8 September 1983)

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CSO: 4009/131

Cryogenics

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M. NAOE  
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ORG: Jiang of Tianjin University, Physics Department; Naoe and Yamanaka  
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TITLE: "Studies on High Speed Sputtering at Low Temperature With Targets  
Facing Each Other and the Formation of Nitrogenized Titanium Film  
by Sputtering"

SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY] in  
Chinese No 3, Jul 85 pp 24-30

ABSTRACT: To obtain high speed sputtering at low temperature without composition divergence two targets of the same size are placed in parallel and face to face in an external magnetic field perpendicular to the normal of the targets. The study of the working principle of this device and the properties of the film indicates that the electrons emitted from the targets effectively ionize the air in the sputtering cavity and form a body of plasma of high density under the action of the magnetic field. The bombardment of high energy electrons on the baseplate can be avoided. Thus, high speed at low temperature without composition divergence is achieved. With this device the properties of the nitrogenized titanium film and the conditions of the formation of the film (the sputtering power, sputtering atmospheric ratio and high frequency bias on the baseplate) were investigated. A film was obtained with  $H_v$  hardness of 3,500-4,000, and the hardness of the film could be measured by the dependence of reflectivity on the wavelength of light. (Paper received 10 September 1983.)

CSO: 4009/1132

AUTHOR: BI Guangquo [3968 0342 0948]

ORG: Department of Radio Engineering

TITLE: "Construction of Orthogonal Complementary Pairs, Sets and Complete Orthogonal Complementary Sets"

SOURCE: Nanjing NANJING GONGXUEYUAN XUEBAO [JOURNAL OF NANJING INSTITUTE OF TECHNOLOGY] in Chinese No 3, 20 Jul 85 pp 1-12

TEXT OF ENGLISH ABSTRACT: Methods for constructing subsets of orthogonal complementary pairs with sequence length of arbitrary powers of two are presented. Orthogonal complementary pairs and sets, and complete orthogonal complementary sets, are expected to apply to multiplex, code-division multiple access (CDMA) and spread spectrum communication systems. (Paper received on 22 Jun 84)

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## Electronics

AUTHOR: WANG Yunyi [3769 5686 0308]  
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TITLE: "W Band Untunable Waveguide Detector"

SOURCE: Nanjing NANJING GONGXUEYUAN XUEBAO [JOURNAL OF NANJING INSTITUTE OF TECHNOLOGY] in Chinese No 3, 20 Jul 85 pp 31-38

TEXT OF ENGLISH ABSTRACT: The design and test for two types of W band untunable waveguide detectors with packaged Schottky diodes have been introduced. The measured performances of the detectors are given. The voltage sensitivity obtained in 5GHz range is higher than 150mV/mW. The VSWR is less than 2 and the square law characteristic is nearly ideal under 70uW level. In addition, these detectors are stable, reliable and easier for changing diodes. (Paper received on 7 September 84)

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- [ 4 ] Wang Yunyi [3769 5686 0308], "Microwave Devices and Circuits", Jiangsu Science & Technology Publishing House, 1981

Electronics

AUTHOR: ZHANG Chuntian [1728 2504 3944]  
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TITLE: "Influence of the Codeword Assignment in DPCM Picture Coding System on the Channel Error Magnitude"  
SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY] in Chinese No 3, Jul 85 pp 47-54

ABSTRACT: Because of the recursive construction of the DPCM [differential pulse code modulation] decoder, when a channel error occurs, the error propagates in the form of a specific error pattern in the reconstructed picture. The initial magnitude of this error pattern is determined by the characteristic of the quantizer, the codeword assignment and the big position of the error. Due to the unequal probability distribution of quantized predictive differences and the nonlinear characteristic of the quantizer, different schemes of the codeword assignment have different effects on the initial error magnitude. In this paper four schemes of the codeword assignment are compared on the condition that a sample has not more than one error bit. The comparison shows that the SM (sign-magnitude) code is the best one in these four schemes, generates the smallest average error magnitude and can reduce the visibility of channel errors. (Paper received 6 December 1984.) (Topic is supported by funds from the Chinese Academy of Sciences.)

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CSO: 4009/1132

AUTHOR: LU Jingchun [4151 2529 2504]  
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et al.

ORG: Department of Electronic Engineering

TITLE: "A Time Base in Quantitative Analysis of High Speed Dynamics"

SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY]  
in Chinese No 4, Dec 84 pp 8-15

TEXT OF ENGLISH ABSTRACT: The time base in quantitative analysis of high-speed dynamics is actually the time base of a monoprocess. A new method is proposed for designing a precise monopulse generator. With this method the authors have made an instrument--a multichannel pulse generator for controlling the holography system. The key pulse intervals and the interval between channels can be pre-set and measured accurately. These intervals are as accurate as those of clock pulses used in the system. Special circuits in the system prevent disturbance due to high-voltage discharge pulses. If a holography laser system is controlled by this instrument, several interferograms describing alterations within several intervals can be obtained at a time in a test. (Paper received on 14 May 1984.)

AUTHOR: WANG Yuhong [3769 0056 1347]  
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TITLE: "Computation Method Using Symbolic Network Function in Network Analysis and Design"

SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY]  
in Chinese No 4, Dec 84 pp 25-39

TEXT OF ENGLISH ABSTRACT: Based on the generating symbolic active network function, this paper presents the generating method of the standard network function (i.e., the method of dimension correction) and the computation method for network function analysis and design. With this computation method we can calculate, analyze and optimally design the amplitude and phase characteristics, group delay of networks, sensitivities of the network function, zeros and poles of the network function and  $W_x$ ,  $Q_x$  in active filters, as well as the network stability, etc. A computer program CNCAD has been written in FORTRAN and tested on a HP-1000 minicomputer. (Paper received on 8 November 1983.)

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TITLE: "A Study of the Treatment of Chromic Wastewater with Granulated  
NCLS3"

SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY]  
in Chinese No 4, Dec 84 pp 47-54

TEXT OF ENGLISH ABSTRACT: This paper deals with the influence of the concentration, flow rate and pH-value of industrial chromic wastewater on the exchange effect of granulated NCLS3 in the treatment of the chromic wastewater, and determines the optimal conditions for its regeneration. Better results have been obtained in the treatment of rinsing water with granulated NCLS3 at Tianjin Jinxi Bicycle Handlebar Factory. (Paper received on 20 January 1984.)

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TITLE: "Application of the Goos-Hänchen Effect in the Passive Q-Switching Laser"

SOURCE: Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY] in Chinese No 4, Dec 84 pp 55-61

TEXT OF ENGLISH ABSTRACT: The Goos-Hänchen effect is discussed briefly in this paper. The expression of the displacement  $D$  on the incident light entering the second medium in the direction of the boundary in the plane of incidence and the calculating curve of  $D/\lambda$  at different incident angles are given. The Goos-Hänchen effect is used for the first time in a passive Q-switching laser, and the Goos-Hänchen effect device is designed. Results indicate that the Goos-Hänchen effect is helpful in obtaining laser pulses with high stability and high power. (Paper received on 10 April 1984.)

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CSO: 4009/1108

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JPRS-CST-85-035  
17 October 1985

ORG: Zhejiang University

TITLE: "Experimental Study of the Flow Characteristics of Pressurized Fluidized Beds"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO [JOURNAL OF ZHEJIANG UNIVERSITY]  
in Chinese Vol 19 No 4, Jul 85 pp 8-18

TEXT OF ENGLISH ABSTRACT: This paper deals mainly with the flow characteristics of pressurized fluidized beds with wide particle size distribution. Glass beads, fluidized bed combustor slag and dolomite were used as the bed materials with an average diameter of 0.38-2.60 mm. The operation pressure varied up to an atmospheric value of 7. The experiment shows that the effects of pressure on the minimum fluidization velocity depend on the fluidization type, i.e., for an aggregative fluidization system, the minimum fluidization velocity decreases with increasing operation pressure, whereas for a particulate fluidization system it is independent of the operation pressure. The coarser the particles are, the stronger the effects of pressure will be. The experiment demonstrates no pressure dependency of the relationships of bed expansion and fluidization number. As the operation pressure was increased, more evenly distributed small bubbles with lower rising velocities and the resulting smoother fluidization were observed. Finally an empirical correlation of the minimum fluidization velocity is given which is appreciable both for atmospheric and pressurized fluidized beds.

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TITLE: "Study of the Hydrodynamic Characteristics in a Fluidized Bed Combustor (Part One)"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO [JOURNAL OF ZHEJIANG UNIVERSITY]  
in Chinese Vol 19 No 4, Jul 85 pp 19-31

TEXT OF ENGLISH ABSTRACT: Fluidized bed combustors use coal with broad size distribution as fuel and operate at high temperatures. However, there is a dearth of information concerning bubble properties under such conditions. Based on the theoretical pressure field around a bubble in the fluidized bed derived by Davidson, we developed a new pair of pressure probes located on a common vertical axis to measure the bubble parameters: bubble rising velocity, bubble depth (diameter), bubbling frequency, etc. The pressure fluctuation signals obtained from a cold model and a combustor are analyzed by statistical methods with the help of a computer. The correlation of the bubble parameters to solid properties and flow conditions by linear regression analysis results in empirical equations. The results show that there is a great difference between bubble parameters in the cold model and the real combustor.

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TITLE: "Investigation of Increasing the Combustion Efficiency of FBC by means of Pulsating Gas Flow"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO [JOURNAL OF ZHEJIANG UNIVERSITY]  
in Chinese Vol 19 No 4, Jul 85 pp 32-41

TEXT OF ENGLISH ABSTRACT: Taking into consideration the lower combustion efficiency and serious pollution of the fly ash from the ordinary fluidized bed combustor (FBC), this paper reports a new method of fluidized bed combustion--pulsing fluidized bed combustion. The authors have carried out a series of experimental research on the flow dynamics and heat transfer behavior in a cold model of the pulsing fluidized bed combustor. Experimental results show that the pulsing fluidized bed has the following advantages which the ordinary fluidized bed does not possess: (1) the minimum fluidizing velocity is lower than that of the conventional FB; (2) the pressure-drop at the fluidization stage is lower than that of the conventional FB; (3) the quantity of particles entrained is less than that of the conventional FB; (4) the heat transfer coefficient between the bed materials and the single particle is about 10 percent higher than that of the conventional FB. We consider pulsing fluidized bed combustion to be an effective way to increase the combustion efficiency and prevent the pollution of fly ash.

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TITLE: "Two Methods for Improving Combustion Performance in FBC"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO [JOURNAL OF ZHEJIANG UNIVERSITY]  
in Chinese Vol 19 No 4, Jul 85 pp 92-103

TEXT OF ENGLISH ABSTRACT: This paper gives the results of the bed material mixing experiment carried out in the experimental fluidized bed (810 x 410 mm and 810 x 100 mm) at Zhejiang University, and the modified diffusion equation solution. The effects and mechanisms of coal spreading air and a distributor with an unequal vent area rate are discussed through the investigation of the combustible concentration and the flue gas concentration distribution of a FBC with a cross section of 3000 x 4500 mm in a power station. The conclusion is that the coal spreading air can improve the combustion performance in the FBC, and the distributor with the unequal vent area rate produces more satisfactory results. The latter does not introduce any difficulties in engineering or extra costs, so it can be easily used in large capacity FBC's with underbed coal feeding, thereby increasing the bed area with each feed point and improving the combustion performance.

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TITLE: "Investigation of the Combustion Characteristics of Coal-Oil Mixture  
in an Oil-burning Boiler"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO [JOURNAL OF ZHEJIANG UNIVERSITY]  
in Chinese Vol 19 No 4, Jul 85 pp 113-125

TEXT OF ENGLISH ABSTRACT: This paper reports the combustion characteristics of coal-oil mixture (COM) in a 100 T/H oil-burning power boiler. Based on the experimental results, measurements and analyses are made for the flow profile, the temperaturatural profile, the profile of gas composition and concentration of solid COM combustion in the oil-burning power boiler. The condition of pollution exhaust is also presented. After some retrofit, COM can be burned in oil-burning boilers with high efficiency.

9717:  
CSO: 4009/288

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TITLE: "A Theoretical and Experimental Study of Optical Fiber Temperature Sensor"

SOURCE: Nanjing NANJING GONGXUEYUAN XUEBAO [JOURNAL OF NANJING INSTITUTE OF TECHNOLOGY] in Chinese No 3, 20 Jul 85 pp 54-61

TEXT OF ENGLISH ABSTRACT: This paper presents a theoretical and experimental study of optical fiber temperature sensor with semiconductor as the sensing element. The experimental results are in good agreement with the theoretical calculations. On the basis of the study, we have designed and made a practical fiber temperature measurement instrument which can provide the measurement within the range of 0-200°C to an accuracy of  $\pm 3^\circ\text{C}$ . (Paper received on 22 September 84)

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## Engineering

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TITLE: "Measurement of Cutoff Wavelength for Double Clad Monomode Fiber--the Modified Polarization Method"

SOURCE: Nanjing NANJING GONGXUEYUAN XUEBAO [JOURNAL OF NANJING INSTITUTE OF TECHNOLOGY] in Chinese No 3, 20 Jul 85 pp 62-66

TEXT OF ENGLISH ABSTRACT: An accurate method of cutoff wavelength measurement for double-clad monomode fiber--the modified polarization method is described. This method can measure the intrinsic cutoff wavelength for a short length of double-clad monomode fiber. The leakage of the second order modes are observed from the curve. The precision of the measurement is less than 3nm, the appropriate length of fiber sample is about 0.3m~10m.

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12949

CSO: 4009/1133

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TITLE: "A Method for Establishing Generalized Variational Principle"

SOURCE: Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 481-488

TEXT OF ENGLISH ABSTRACT: A method for establishing a generalized variational principle is proposed in this paper. It is based on the analysis of mechanical meaning and can be applied to problems in which the variational principles are needed but no corresponding variational principle is available. In this paper, the Hu-Washizu generalized variational principle and Hu's generalized principle of complementary energy are derived from the mechanical meaning instead of from the generalization of the principle of minimum potential energy, and the correct proofs of these two generalized variational principles are given. It is also proved that it is wrong to consider  $\sigma_{ij}$ ,  $\epsilon_{ij}$  and  $u_i$  to be variables which are independent of each other because these three kinds of variables are all contained in these two generalized variational principles. The conditions for using these two variational principles correctly are also explained. (Paper received on 4 May 1984.)

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TITLE: "Dynamic Stability and Phase Planar Property for Radial Sector Cyclotrons with N-folded Symmetry"

SOURCE: Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 499-506

TEXT OF ENGLISH ABSTRACT: The particle nonlinear motion equation for a radial sector cyclotron with N-folded symmetry is derived. The betatron oscillation frequencies with  $N=4, 5, 6, 8, 10$  and the phase planar properties before and after  $v_x = 4/3$  resonance with  $N=4, f=0.578$  are analyzed using a numerical method. The dynamic stabilities and nonlinear properties are discussed, and the results, when compared with Gordon's, show that both are consistent when nonlinear terms are neglected. (Paper received on 3 March 1984.)

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TITLE: "A New Criterion of Combined Type Crack--The Criterion of Minimum Distance  $r_{\min}$  in Plastic Region"

SOURCE: Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 507-518

TEXT OF ENGLISH ABSTRACT: The existence of the plastic area around the crack tip is an important factor against cracking. In this plastic region, the cracking most likely develops in the direction in which the distance from the existing crack tip to the plastic region edge is the shortest one.

Substituting the stress components at the crack tip for a combined cracking into R. von Mises' equation of yielding conditions, the boundary equation for the plastic region around the crack tip can be expressed as:

$$r = \frac{9}{2\sigma_1^2} \left[ \left( \frac{5}{36} + \frac{1}{18} \cos \theta - \frac{1}{12} \cos^2 \theta \right) K_1^2 + \left( \frac{1}{3} \cos \theta \sin \theta - \frac{1}{9} \sin^2 \theta \right) K_1 K_2 + \left( \frac{5}{36} - \frac{1}{18} \cos \theta + \frac{1}{4} \cos^2 \theta \right) K_2^2 + \frac{1}{3} K_2^3 \right]$$

where  $r$  is the distance from the crack tip to the boundary of the plastic region. The direction in which the cracking develops can be determined by the following conditions:

$$\frac{\partial r}{\partial \theta} = 0, \quad \frac{\partial^2 r}{\partial \theta^2} > 0$$

One form of the material failures is the slipping under the action of shear stress. Under the conditions of complex stress, the octahedral shear stress on a point around the crack tip is

$$\tau_{\text{oct}} = \frac{1}{\sqrt{3}} \left\{ \left( \frac{5}{36} + \frac{1}{18} \cos \theta - \frac{1}{12} \cos^2 \theta \right) K_1^2 + \left( \frac{1}{3} \cos \theta \sin \theta - \frac{1}{9} \sin^2 \theta \right) K_1 K_2 + \left( \frac{5}{36} - \frac{1}{18} \cos \theta + \frac{1}{4} \cos^2 \theta \right) K_2^2 + \frac{1}{3} K_2^3 \right\}^{\frac{1}{2}}$$

$$\text{let } B = \left\{ \left( \frac{5}{36} + \frac{1}{18} \cos \theta - \frac{1}{12} \cos^2 \theta \right) K_1^2 + \left( \frac{1}{3} \cos \theta \sin \theta - \frac{1}{9} \sin^2 \theta \right) K_1 K_2 + \left( \frac{5}{36} - \frac{1}{18} \cos \theta + \frac{1}{4} \cos^2 \theta \right) K_2^2 + \frac{1}{3} K_2^3 \right\}^{\frac{1}{2}}$$

Here,  $B$  gives the factor of the octahedral shear stress, which relates to the size, pattern of the crack and the exerted stress. Its magnitude reflects the strength of the stress field around the crack tip. Therefore, it can be considered as the criterion for combined type crack development. When  $B$  reaches the critical value of  $B_c$ , i.e.,  $B=B_c$ , the crack developing occurs.

Based on the above theorem, the following relationship can be obtained for the problem of an I-type crack:

$$B_c = \frac{1}{3} K_{Ic} .$$

This criterion is established based on the octahedral shear stress of elastic mechanics and R. von Mises' yielding condition, which related the fracture to the traditional theorem of mechanics. Therefore, it is a clear physical concept and simple calculation procedure. The computations show results which are more reasonable and accurate than those of  $S$ ,  $(\sigma_\theta)_{\max}$  and  $G$  criteria. (Paper received in March 1982.)

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TITLE: "Selection of the Optimum Parameters for Sandwich Construction with  
Honeycomb Core"

SOURCE: Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND  
MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 541-549

TEXT OF ENGLISH ABSTRACT: The minimum weight of sandwich construction, regarded as an objective function, is discussed. Under the given constraint condition of the strength or stiffness, the four optimum parameters of sandwich construction with a honeycomb core (thickness of the face  $t_f$ , thickness of the honeycomb core  $h_c$ , thickness of the honeycomb wall  $t_s$ , side length of the honeycomb cell  $c$ ) are evaluated. By using the constraint condition of strength, an equation of high degree is finally solved. In the constraint condition of stiffness, the constraint optimization problem is treated as a nonconstraint optimization problem using a method which obtains an extreme value solution by undetermined parameter multiplication. A discussion is given of the results. (Paper received on 3 January 1981.)

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TITLE: "The Method of Matrices Conjoining Multiplication for the Problem of Circular Arc Corrugated Diaphragm"

SOURCE: Chongqing YINGYONG SHUXUE HE LIXUE [APPLIED MATHEMATICS AND MECHANICS] in Chinese Vol 6 No 6, Jun 85 pp 551-566

TEXT OF ENGLISH ABSTRACT: The circular arc corrugated diaphragms are taken in this paper as composite structures of several sections of the ring shells and a central circular plate. Transfer matrices and link matrices are derived using Professor Qian Weizhang's [6929 0251 7022] general solutions of ring shells and the perturbation theory of circular thin plates. Through the method of matrices conjoint multiplication, the linear exact solution and nonlinear solution are obtained. The results agree with those of the experiments presented by W.A. Wildhack. (Paper received on 10 July 1984.)

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CSO: 4009/1115

Mathematics

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TITLE: "Code (Base Language) Sequences and the Optimality for Prefix-Codes in the Sense of Length-Preserving"

SOURCE: Lanzhou LANZHOU DAXUE XUEBAO (ZIRAN KEXUE BAN) [JOURNAL OF LANZHOU UNIVERSITY (NATURAL SCIENCE EDITION)] in Chinese Vol 21 No 2, 28 Jun 85 pp 1-5

ABSTRACT: Code sequences are defined over an alphabet  $X$  and are characterized: a nonnegative sequence  $\{k_i\}$  is a code sequence over  $X$  if and only if  $\{k_i\}$  satisfies the following inequality:

$$\sum_{i=1}^n k_i N^{n-i} \leq N^n, \quad n = 1, 2, \dots,$$

where  $N = |X|$ .

Using this inequality results are obtained as follows:

- (1) Every code is length-preserving equivalent to a prefix code.
- (2) A code  $C$  is a maximal code if the code sequence  $\{k_i\}$  of  $C$  satisfies

$$\sum_{i=1}^{\infty} k_i / N^i = 1.$$

- (3) A finite prefix code is a maximal prefix code if and only if the condition (2) holds. (Paper received 20 February 1984; and in part supported by Chinese Academy of Sciences Funds)

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Physics

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TITLE: "Duoplasmatron Source for the Production of Intense DC Ion Currents"

SOURCE: Lanzhou LANZHOU DAXUE XUEBAO (ZIRAN KEXUE BAN) [JOURNAL OF LANZHOU UNIVERSITY (NATURAL SCIENCE EDITION)] in Chinese Vol 21 No 2,  
28 Jan 85 pp 56-60

ABSTRACT: A source based on the "duoplasmatron" principle suggested by M. Von Ardenne for the production of intense DC ion currents has been investigated. Constant hydrogen ion currents up to 100 mA have been obtained under extracting voltage of 18 kv. The mass ratios of hydrogen ions have been analyzed by a 90° deflection magnetic analyzer for currents up to 50 mA. In this range, up to 64 percent of the total current is  $H_{1+}$ . The emittance of an ion beam from an ion source has been determined by both the multislit-probe and the photocopy paper methods. A typical normalized emittance (phase space area  $\times \beta\gamma/\pi$ ) of 0.48 mm·mrad and brightness of  $4.4 \times 10^6$  A/cm<sup>2</sup>·rad<sup>2</sup> have been obtained for 50 mA beams at 16 kv accelerating voltage. The operating characteristics of the source were investigated. (Paper received 24 October 1983)

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Semiconductors

JPRS-CST-85-035  
17 October 1985

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TITLE: "High Voltage Nanosecond Pulse Circuits With Semiconductor Devices"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 350-354

TEXT OF ENGLISH ABSTRACT: A number of semiconductor circuits used for the generation of high voltage nanosecond  $\delta$ -function, rectangular and exponential decap waveform are introduced. The experimental results indicate that the semiconductor devices are as good as vacuum devices in providing high voltage nanosecond pulses. (Paper received on 7 January 85)

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TITLE: "Preparation and Investigation of Amorphous Gallium Arsenide Films"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 355-361

TEXT OF ENGLISH ABSTRACT: A new method for the preparation of a-GaAs films--  
Plasma Enhanced Chemical Transport Deposition (PECTD) is described. The  
experimental results indicate that a bright smooth surface, a nearly  
stoichiometric composition and a good reproducibility of the a-GaAs films  
could be obtained if proper technological conditions were selected and  
controlled. The growth mechanism of PECTD is also discussed. (Paper received  
on 15 October 84)

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TITLE: "Comparative Studies of Electron Affinities and Work Functions for GaAs and Si"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 6, No 4, Jul 85 pp 362-368

TEXT OF ENGLISH ABSTRACT:

UPS involving core level photoemission peaks (Ga 3d for GaAs and Si 2p for Si) is measured for the (111), (110), (11 $\bar{1}$ ), and (00 $\bar{1}$ ) surfaces of GaAs and Si using the light from a helium lamp (21.2 eV and 40.8 eV) and from the Berlin synchrotron radiation source BESSY (108.6 eV), respectively. These surfaces are prepared by ion bombardment and annealing on cylindrically shaped GaAs and Si crystals with [110] as their axis. The GaAs cylinder is in addition prepared by molecular beam epitaxy yielding As-rich phases on (11 $\bar{1}$ ) and (00 $\bar{1}$ ). The work function  $\phi$  and the electron affinity  $\chi$  are evaluated from the low energy (secondary electron) threshold and the energy position of the core level photoemission peak. It is shown that due to the crystal polarity and differences in surface composition, the electron affinity depends strongly on the orientation for GaAs. For Si, the missing bulk polarity is responsible for the small variations of  $\chi$ , which may be caused by the different surface reconstructions. On GaAs, the variation of  $\phi$  and  $\chi$  are essentially parallel indicating no strong band bending variations. On Si, however, the relatively strong variations of  $\phi$  indicate strong variations of the band bending. (Paper received on 3 September 84)

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TITLE: "Ruby Laser Induced Oxidation of Si (100) Surfaces"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 379-385

TEXT OF ENGLISH ABSTRACT: Various experimental techniques including sputtered AES, Normaski technique and IR absorption spectrum have been used to study the Si (100) surfaces irradiated by a Q switched ruby laser in the air. The energy densities of the pulses are (0.8-2.5 J·cm<sup>-2</sup>), pulse width ~30ns. The results show no evidence for >10Å SiO<sub>2</sub> layer on the surface, and the depth of oxygen contamination is only ~50 Å after irradiation. (Paper received on 30 July 84)

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TITLE: "Relation Between 0.72 eV Electron Trap and Growth Conditions in LPE-GaAs"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 386-392

TEXT OF ENGLISH ABSTRACT: The origin of deep electron trap ( $E_c-0.72$  eV) in LPE-GaAs is examined using the DLTS method. Through varying growth conditions the authors found that the concentration of the electron trap is influenced by the growth temperature, cooling rate and doping condition of the layer. It is supposed that the electron trap is a complex formed by point defects, oxygen and carbon impurities in the layer. (Paper received on 26 January 84)

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TITLE: "Ion-implanted Silicon Detectors With High Sensitivity to Blue-light"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 6, No 4, Jul 85 pp 406-412

TEXT OF ENGLISH ABSTRACT: The results of CW CO<sub>2</sub>-laser annealing on ionimplanted silicon photodiodes are reported. Compared with furnace annealing, the laser annealing diodes have shorter wavelength of maximum responsivity and higher blue-light sensitivity. The quantum efficiency is 0.64 at 4000 A. The superiority of CW CO<sub>2</sub>-laser annealing over furnace annealing is explained through the measurements of junction depth, the impurity profile and the observation of defects. (Paper received on 20 July 84)

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TITLE: "GaAs Hall Elements Fabricated By Epitaxial Growth"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 413-419

TEXT OF ENGLISH ABSTRACT: A planar-structure Hall element has been fabricated using liquid or vapor phase epitaxial growth of a n-type layer on semi-insulating GaAs substrates. This Hall element generates a high Hall-sensitivity, 30 mV/makG for 1 k $\Omega$  resistance, with a low temperature coefficient less than 0.01 percent/°C in a temperature range from -50 to 250° C. (Paper received on 14 July 84)

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TITLE: "Conductivity Performance of GD Poly-crystalline Silicon-like Films"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 420-422

TEXT OF ENGLISH ABSTRACT: The hydrogenated poly-crystalline silicon-like films can be prepared by using increased r.f. deposition power in GD method. The hydrogen atoms compensates the defects in grain boundaries. Therefore, the barrier of grain boundaries decreases and the conductivity increases by three orders of magnitude. This kind of poly-crystalline silicon films has some advantages in manufacturing poly-silicon devices. (Paper received on 11 September 84)

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TITLE: "Beryllium Ion Implantation in Semi-insulating GaAs Substrates"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 6, No 4, Jul 85 pp 433-436

TEXT OF ENGLISH ABSTRACT: Ion implantation of Be into Cr-doped semi-insulating GaAs substrates has been studied. The carrier concentration profiles, residual damage and Be atomic profiles are determined by the C-V method, back scattering technique and secondary ion mass spectrometry. It is shown that high electrical activation, approximate ideal Gaussian distribution and higher mobility can be obtained by means of capless annealing technique at temperatures of 600-700°C. (Paper received on 18 October 84)

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TITLE: "Development of High Efficiency Polycrystalline Silicon Solar Cells  
by Ion Implantation and CW-CO<sub>2</sub> Laser Annealing"

SOURCE: Beijing TAIYANGNENG XUEBAO [ACTA ENERGIAE SOLARIS SINICA] in Chinese  
Vol 6 No 3, Jul 85 pp 245-251

TEXT OF ENGLISH ABSTRACT: In this paper, the development of polycrystalline silicon solar cells by ion implantation followed by CW-CO<sub>2</sub> laser annealing is reported. In fabricating polycrystalline silicon solar cells, some measurements, such as ellipsometry, Hall effect, ion probe, etc., are used for the study of the effect of laser power density and irradiation time on annealing results. The ion implanted/laser annealed polycrystalline silicon solar cells developed exhibit AMI conversion efficiencies exceeding 13 percent (effective area).

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TITLE: "Black Cobalt as a High Temperature Selective Absorber Surface"

SOURCE: Beijing TAIYANGNENG XUEBAO [ACTA ENERGIAE SOLARIS SINICA] in Chinese  
Vol 6 No 3, Jul 85 pp 264-267

TEXT OF ENGLISH ABSTRACT: In this paper, the method of preparation of cobalt oxide as a high temperature spectrum selective absorber coating used in solar energy devices is described. The optical and mechanical properties of the coating are discussed, and the composition of the coating is analyzed. The integrated solar absorptance of the coating is 0.92-0.89, and the infrared emittance at 70°C is 0.20-0.24. The coating has good adhesion to the substrates and is stable up to 600°C.

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TITLE: "An Investigation of Proton Implantation in Grate Inversion Layer MIS Solar Cells"

SOURCE: Beijing TAIYANGNENG XUEBAO [ACTA ENERGIAE SOLARIS SINICA] in Chinese  
Vol 6 No 3, Jul 85 pp 268-272

TEXT OF ENGLISH ABSTRACT: Grate inversion layer MIS solar cells rely on the charge-inducing properties of antireflection coatings (SiO) to achieve good device performance. However, two related problems are as follows: (1) Because the rate of vaporizing SiO can not be controlled appropriately, there are no inversion layers in the cells. (2) These properties reduce with time because the induced charge in SiO film is neutralized by the charge outside the SiO film, thereby preventing the achievement of good device performance. This paper presents a method in which the proton implantation forms an inversion layer. The authors use the above method for SiO film in transparent metal MIS cells and compare the results with those of grate inversion layer MIS solar cells. It is proved that the proton implantation method is more effective.

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